

Bridges Design Diploma

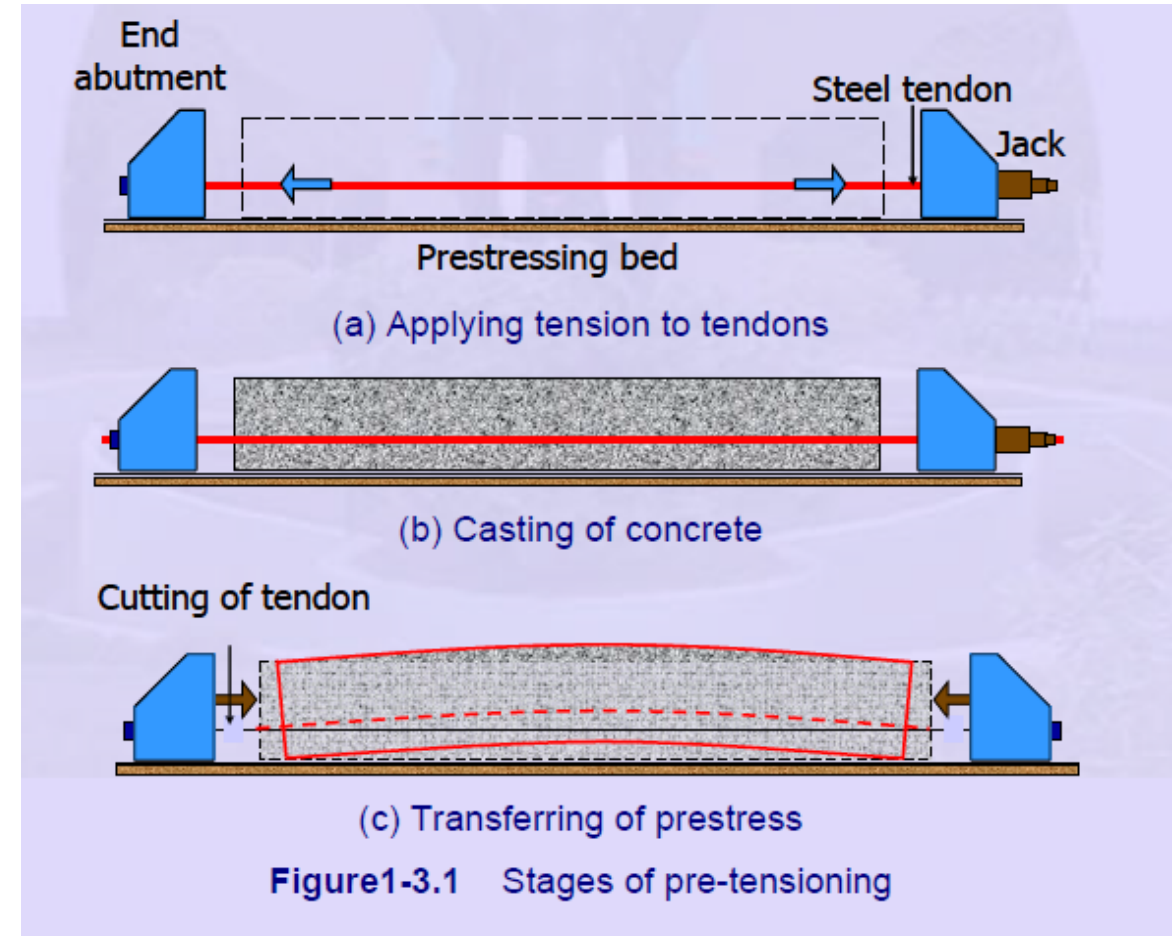
By EngoSoft training center

By Eng. Amr Ali
Bridges/Structural Engineer



Pre-tensioning VS Post-tensioning

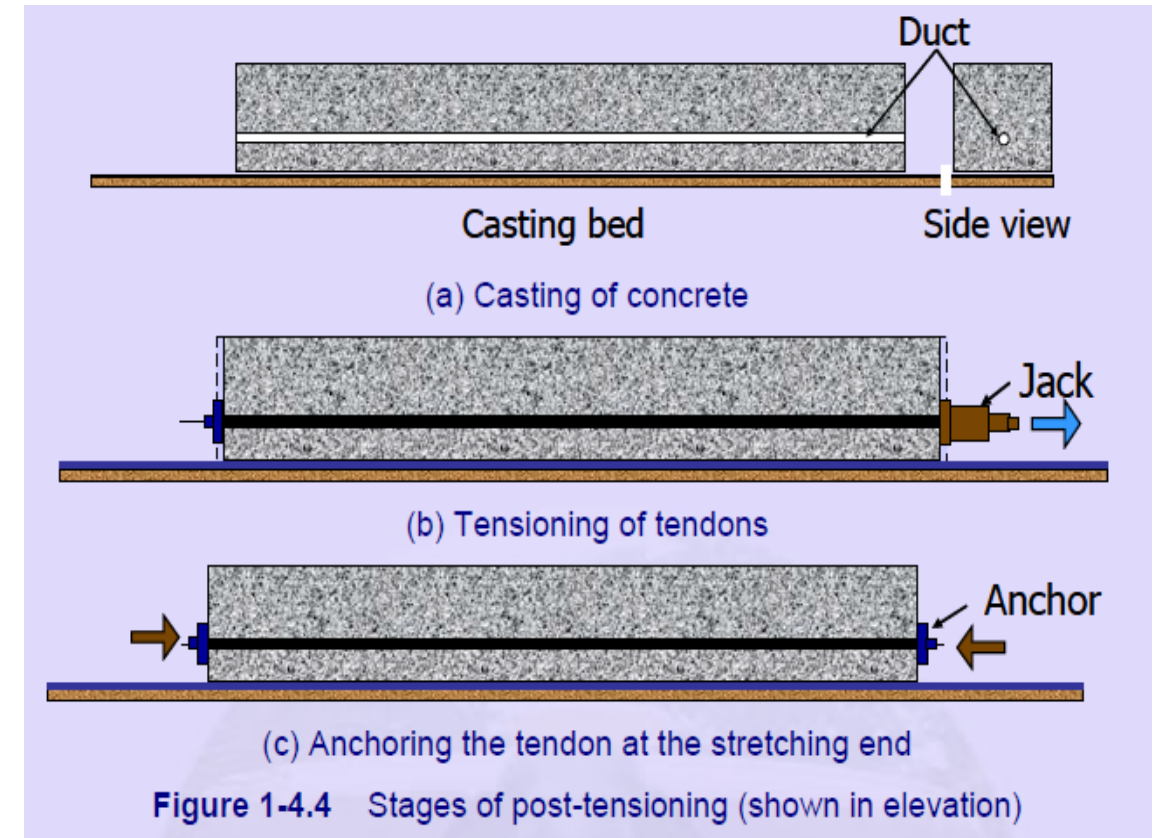
- Pre-Tensioning
- In this method the tendons(group of wires) are pulled between two end bulkhead prior to casting . This pre-stress is later transferred to concrete due to bonding between the concrete and tendons .



Pre-Tensioning process

Pre-tensioning VS Post-tensioning

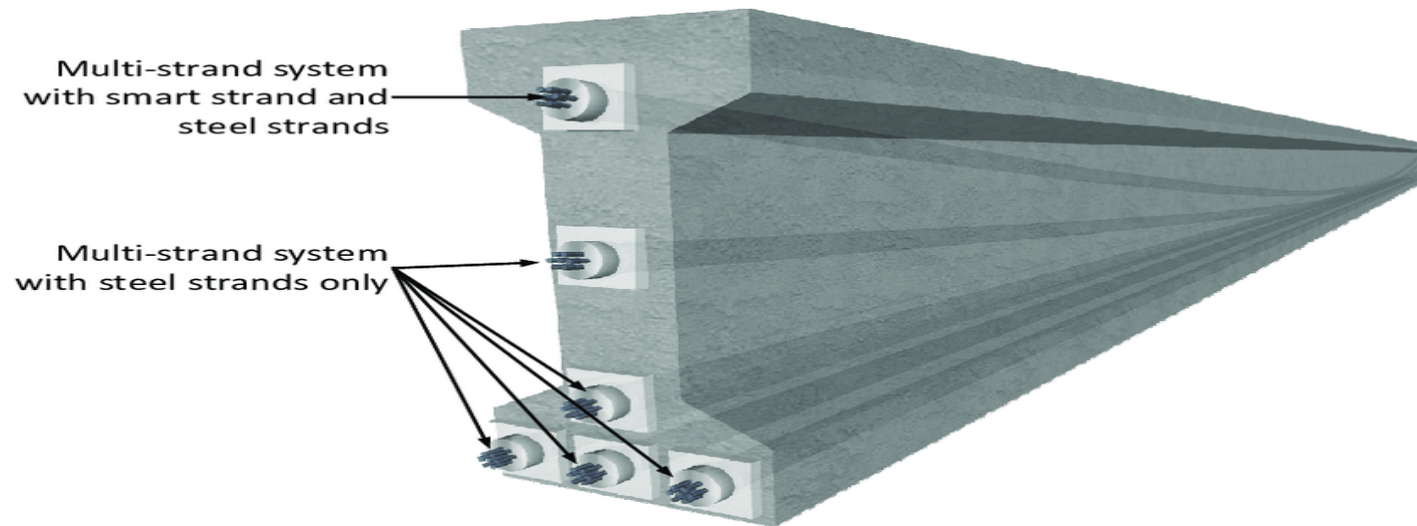
- Post-tensioning
- In this process first the casting of structure is done and later the tensioning is done. Stressing in Post-Tensioning is done in two-stages in which the order of selection of tendon is done based on the drawing provided.



Post-Tensioning process

Pre-tensioning VS Post-tensioning

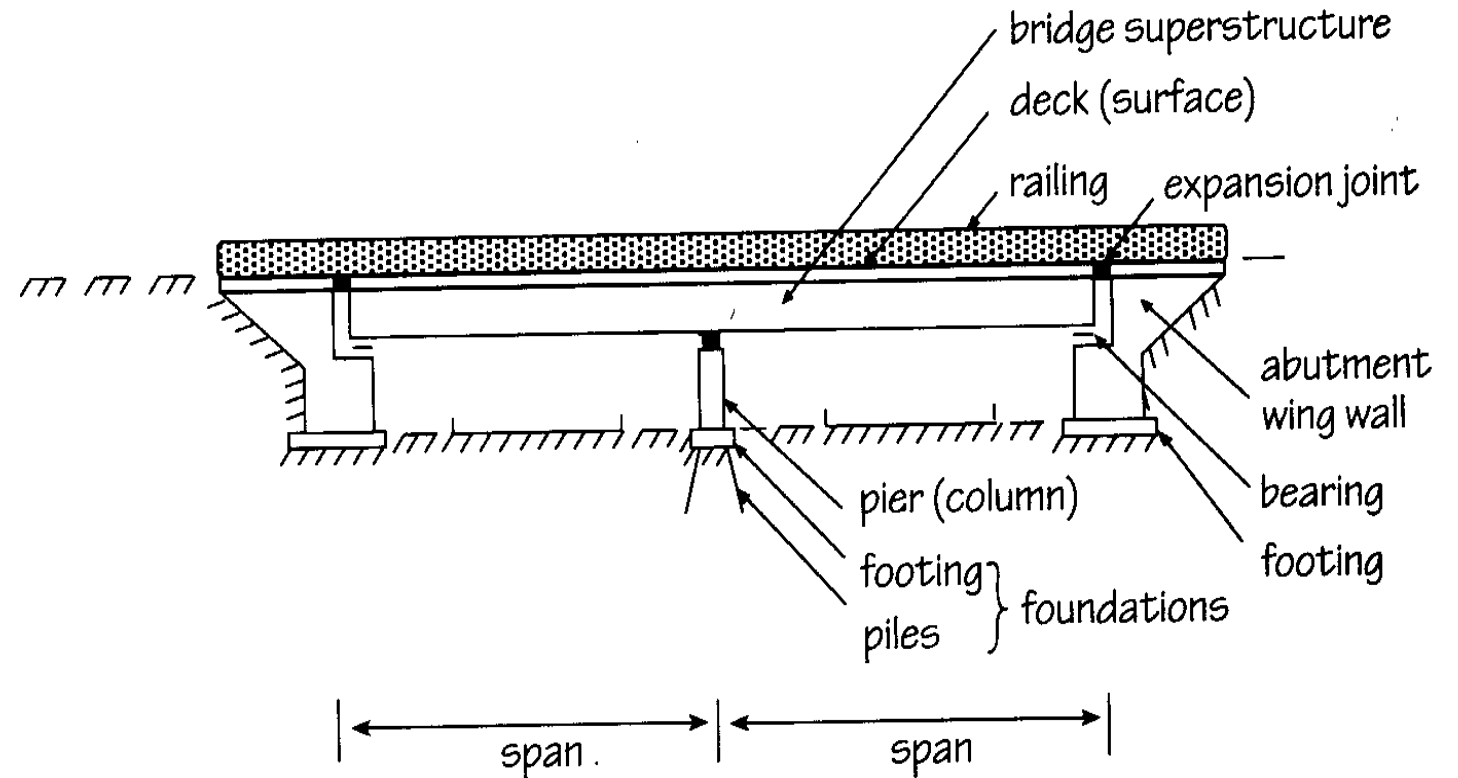
- Post-tensioning
- This tendons are installed via duct pipe in the structure (PSC Girder) which after stressing process are sealed with a mix of cement + water + intraplaster (sika or civax-100). This process is known as **Grouting**.



Bridge component definitions

Components definition

- Sub Structure
- Piles.
- Footing.
- Pier.
- Abutment.
- Bearing.



TYPICAL BRIDGE ELEMENTS

Bridge component definitions



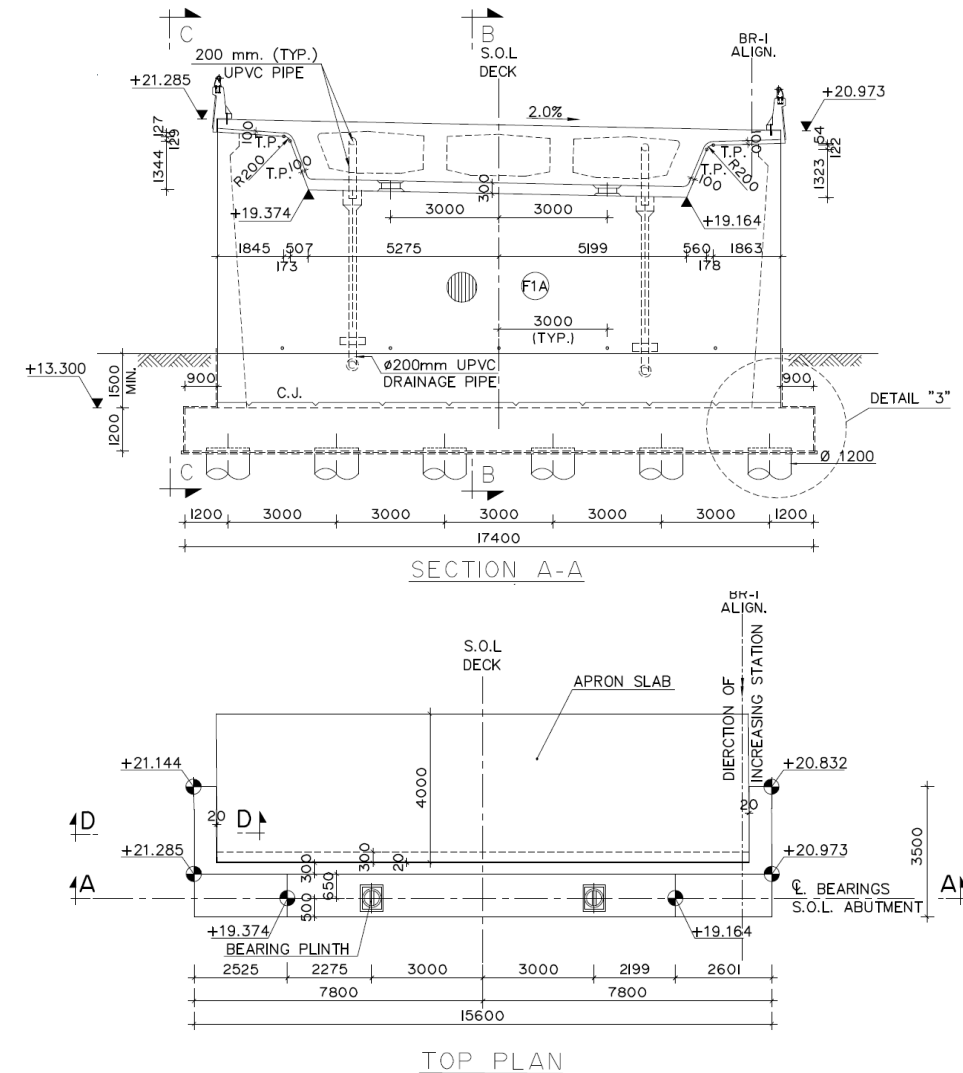
Components definition

- Sub Structure
- The substructure consists of all of the parts that support the superstructure.
- The main components are abutments or end-bents, piers or interior bents, footings, and piling.

Bridge component definitions

Components definition

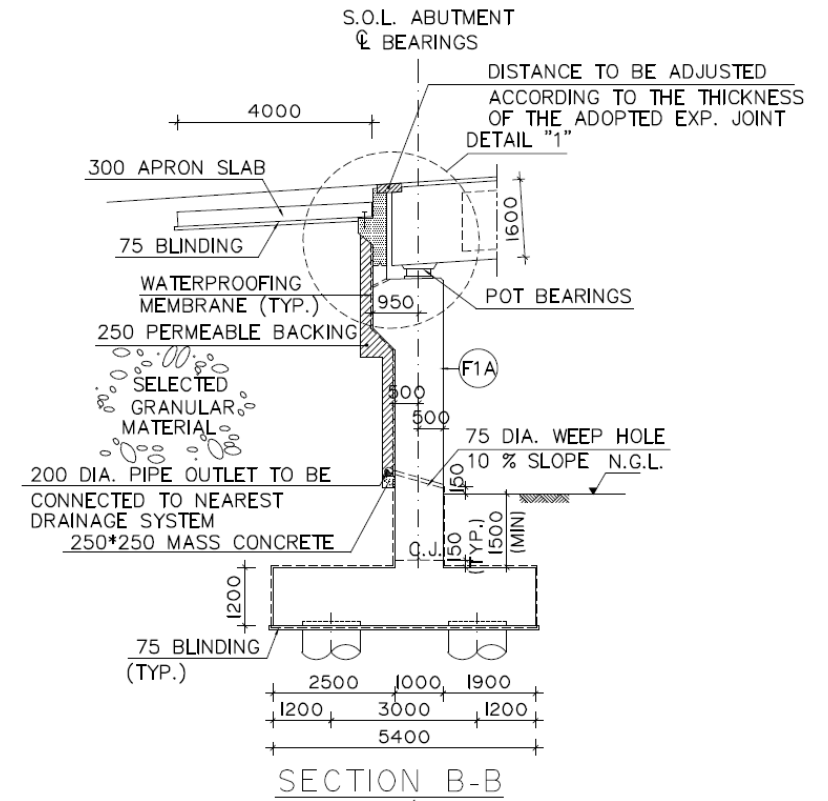
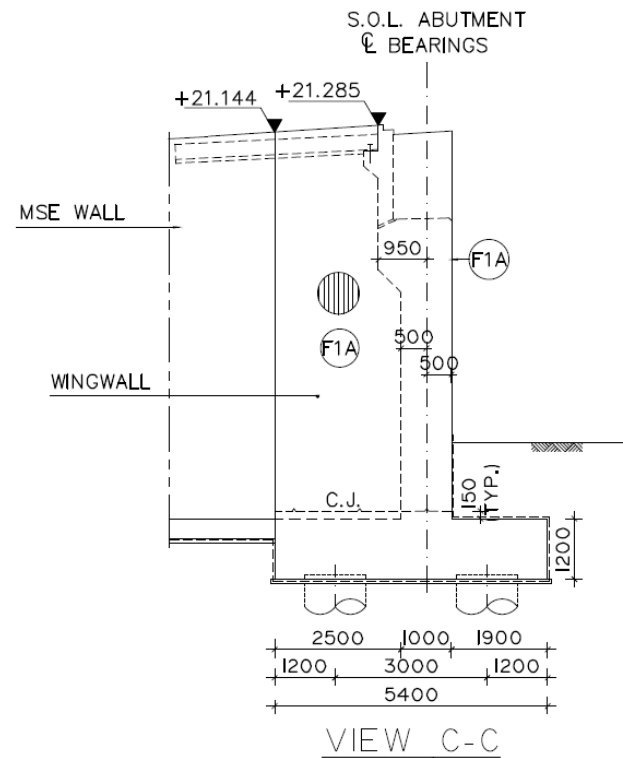
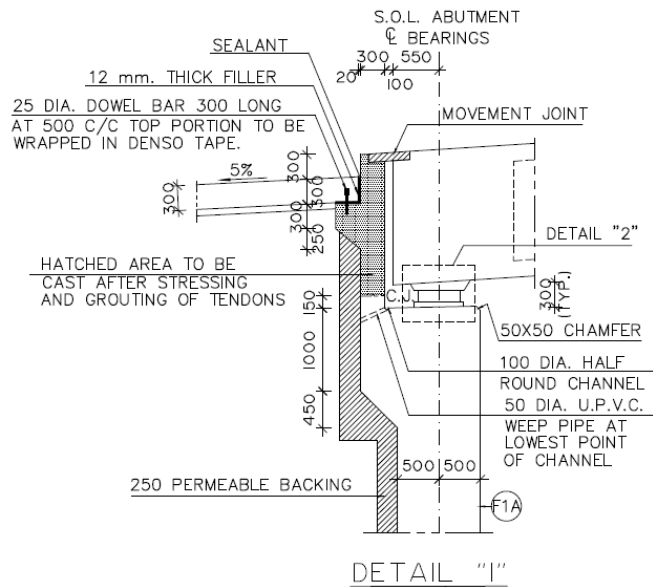
- Abutment
- Abutments support the extreme ends of the bridge and confine the approach embankment, allowing the embankment to be built up to grade with the planned bridge deck.



Bridge component definitions

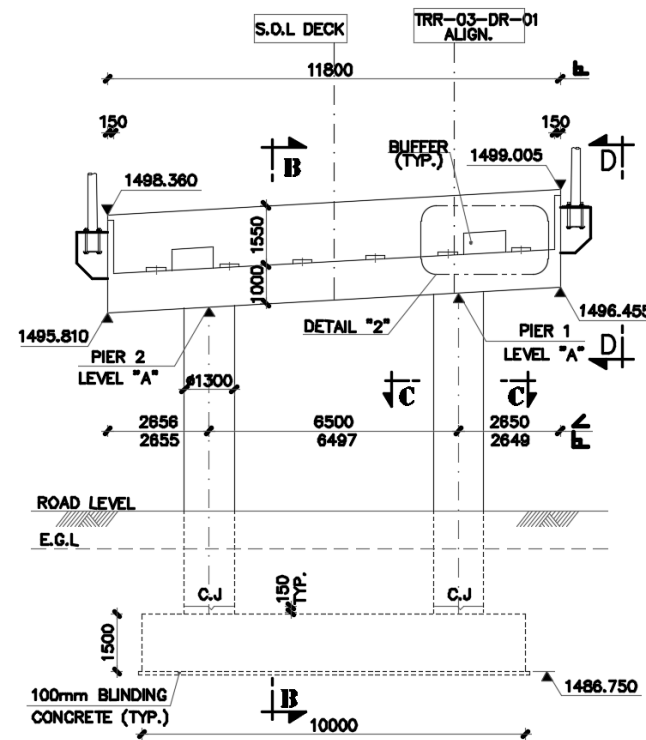
Components definition

- Abutment**

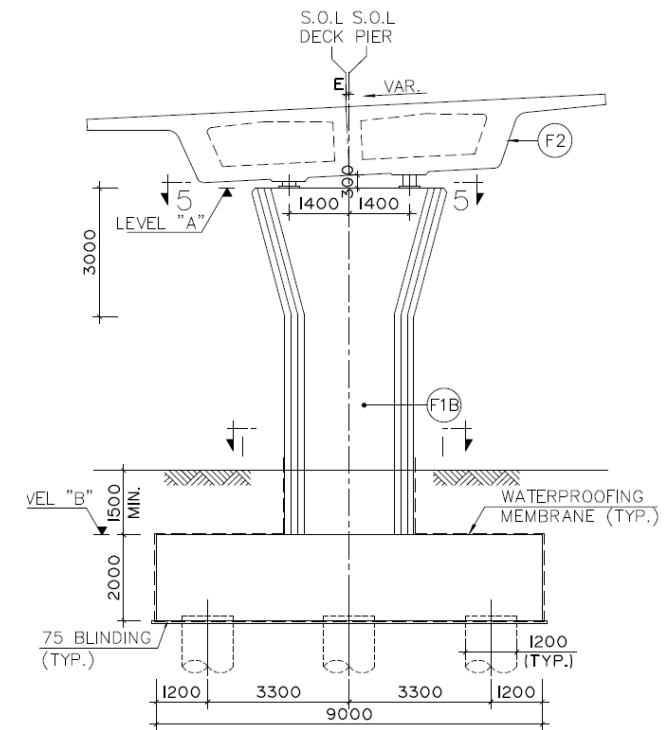


Components definition

- Pier / Bent
- When a bridge is too long to be supported by abutments alone, piers or interior bents are built to provide intermediate support.
- Although the terms may be used interchangeably, a pier generally is built as a solid wall, while bents are usually built with columns.



Bent

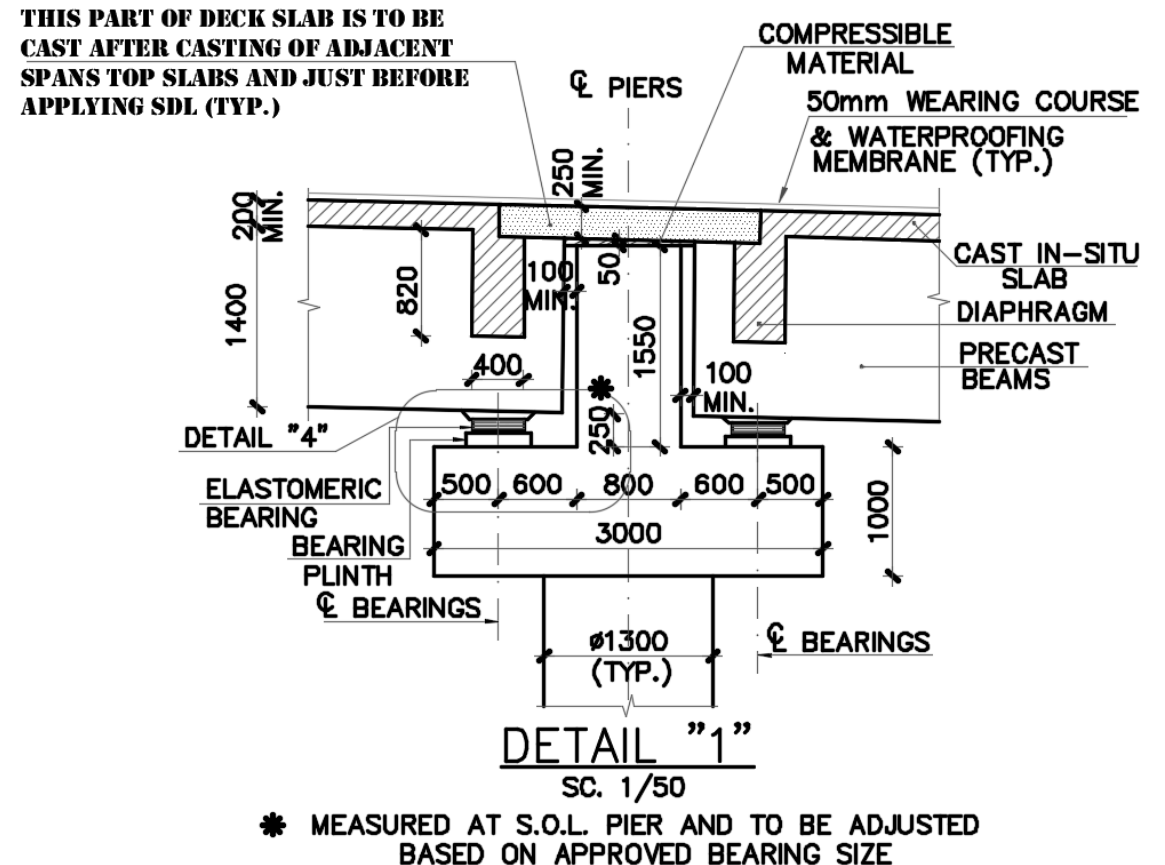


Pier

Bridge component definitions

Components definition

- Pier Cap & pedestal
- The top part of abutments, piers, and bents is called the cap.
- The structural members rest on raised, pedestal-like areas on top of the cap called the bridge seats.

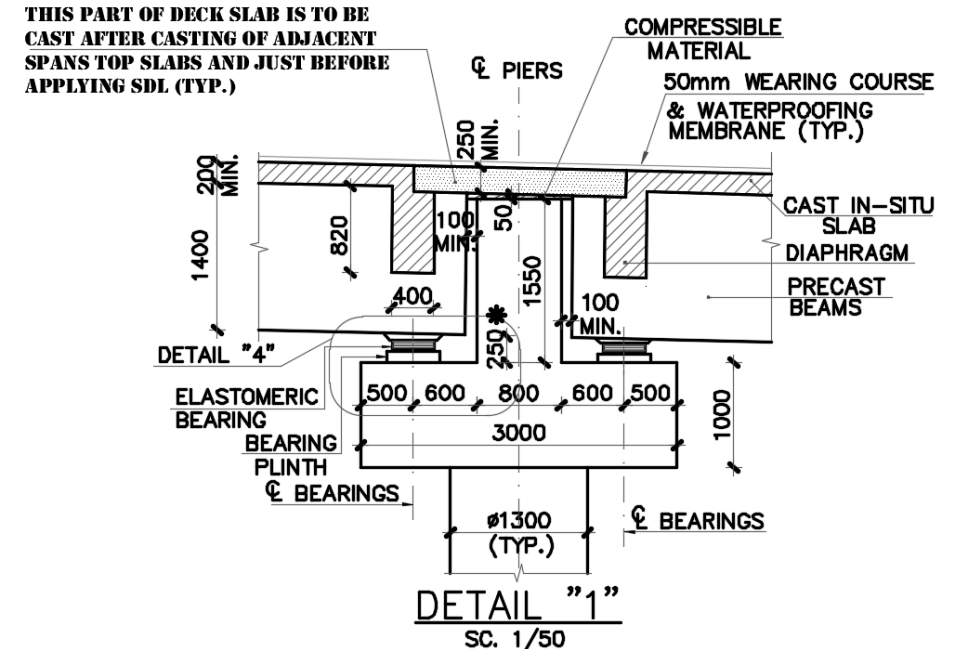
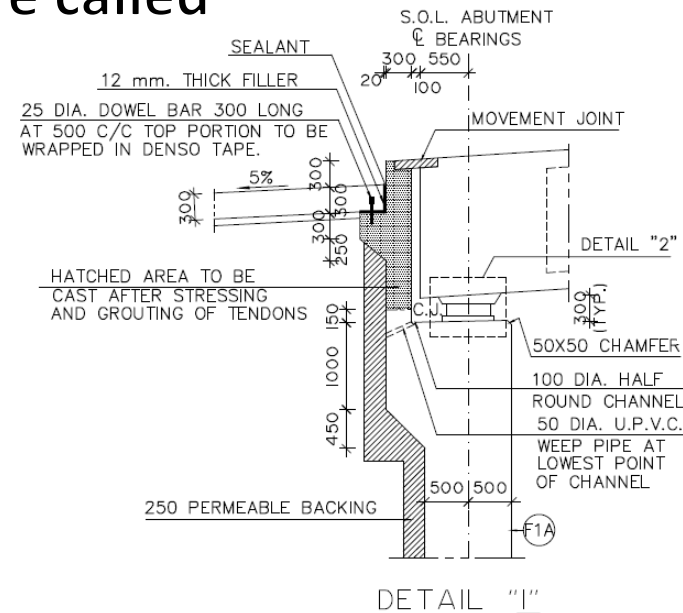
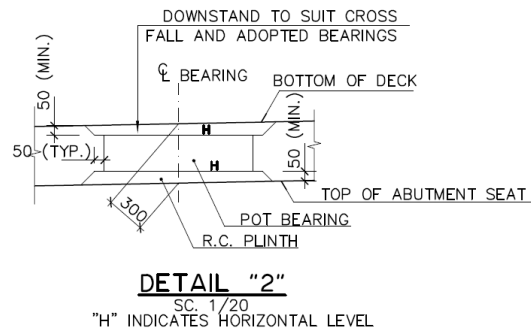


Pier Cap & pedestal

Bridge component definitions

Components definition

- **Bearings**
- The devices that are used to connect the structural members to the bridge seats are called shoes or bearings.



* MEASURED AT S.O.L. PIER AND TO BE ADJUSTED BASED ON APPROVED BEARING SIZE

Bearings in beam type bridge

Bearing @ abutment

Bridge component definitions

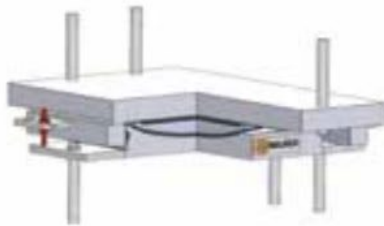
Components definition

- Bearing



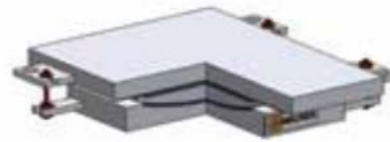
>> FIXED:

The bearing transmits external horizontal forces both in longitudinal and transversal direction, rotations enabled, whereas displacements are not allowed.



>> GUIDED-SLIDING:

The bearing accommodates for displacements in one plane direction and transmits external horizontal forces in the other, rotations enabled.

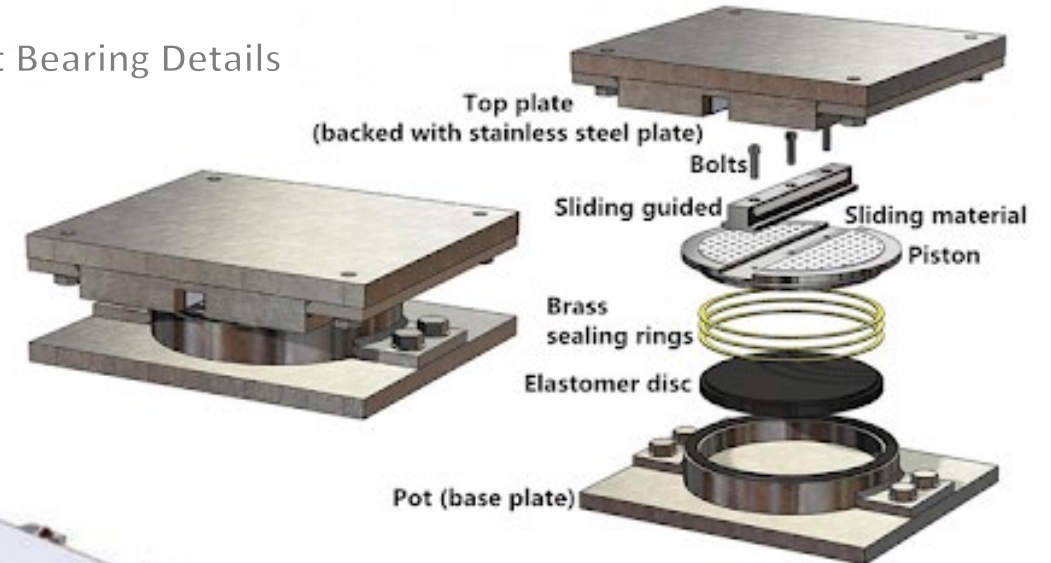


>> FREE-SLIDING:

The bearing accommodates for displacements in both plane directions, rotations enabled, and does not transmit any horizontal forces.

Spherical Bearing Details

Pot Bearing Details

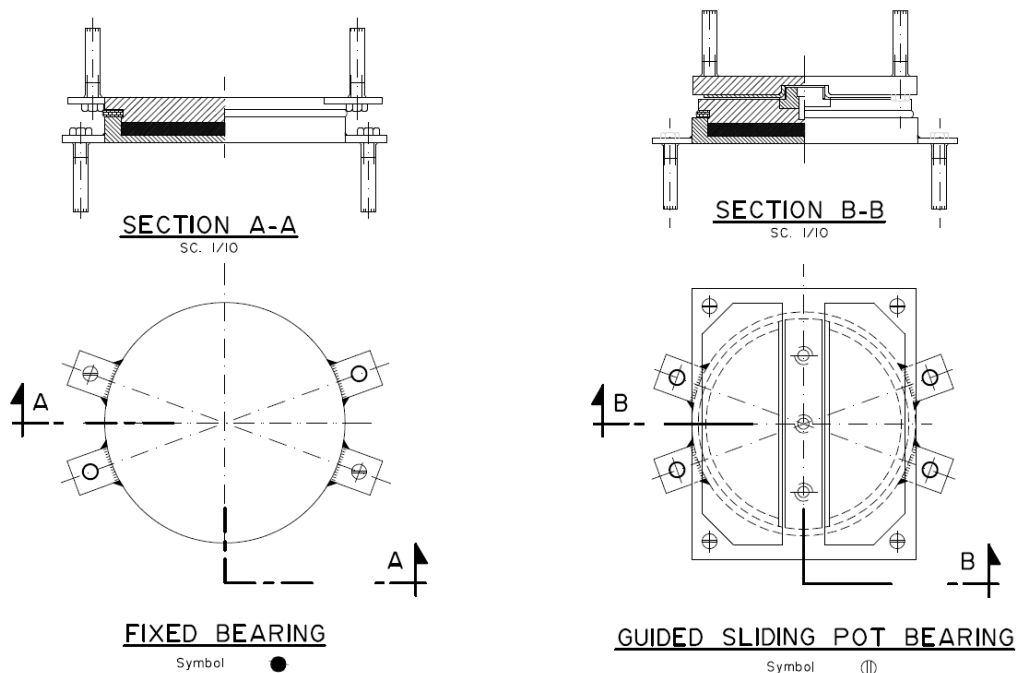


Elastomeric bearings

Bridge component definitions

Components definition

- Bearings**



Pot Bearing Details

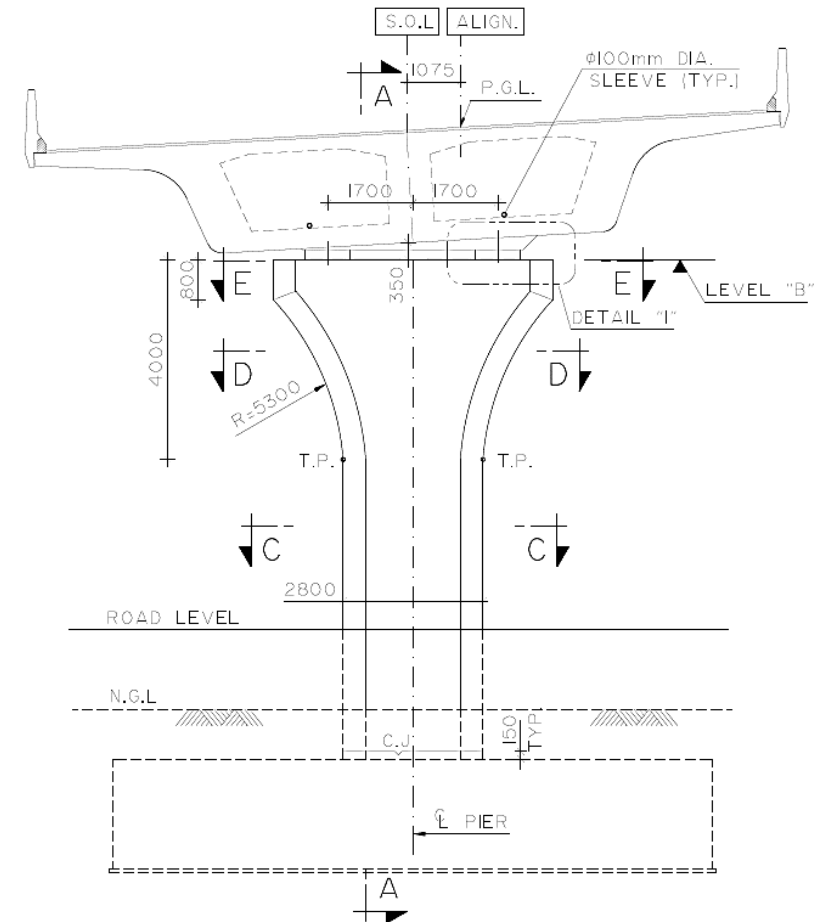
BEARING SCHEDULE

LOCATION	BEARING			AASHTO LRFD LOAD COMBINATION			
	TYPE	NUMBER				MAX.	2000
ABUTMENTS & PIERS	ELASTOMERIC	84	DESIGN LOAD EFFECTS (KN)	SERVICE LIMIT STATE	VERTICAL	MIN.	500
					TRANSVERSE		10
					LONGITUDINAL		50
				STRENGTH LIMIT STATE	VERTICAL		3100
					TRANSVERSE		25
					LONGITUDINAL		80
				EXTREME LIMIT STATE	VERTICAL		1650
					TRANSVERSE		45
					LONGITUDINAL		80
			TRANSLATION (mm)	SERVICE LIMIT STATE	IRREVERSIBLE	TRANSVERSE	5
						LONGITUDINAL	25
					REVERSIBLE	TRANSVERSE	±10
						LONGITUDINAL	±25
				STRENGTH LIMIT STATE	IRREVERSIBLE	TRANSVERSE	6
						LONGITUDINAL	30
					REVERSIBLE	TRANSVERSE	±12
						LONGITUDINAL	±35
				EXTREME LIMIT STATE	IRREVERSIBLE	TRANSVERSE	6
						LONGITUDINAL	30
					REVERSIBLE	TRANSVERSE	-
						LONGITUDINAL	-

Bridge component definitions

Components definition

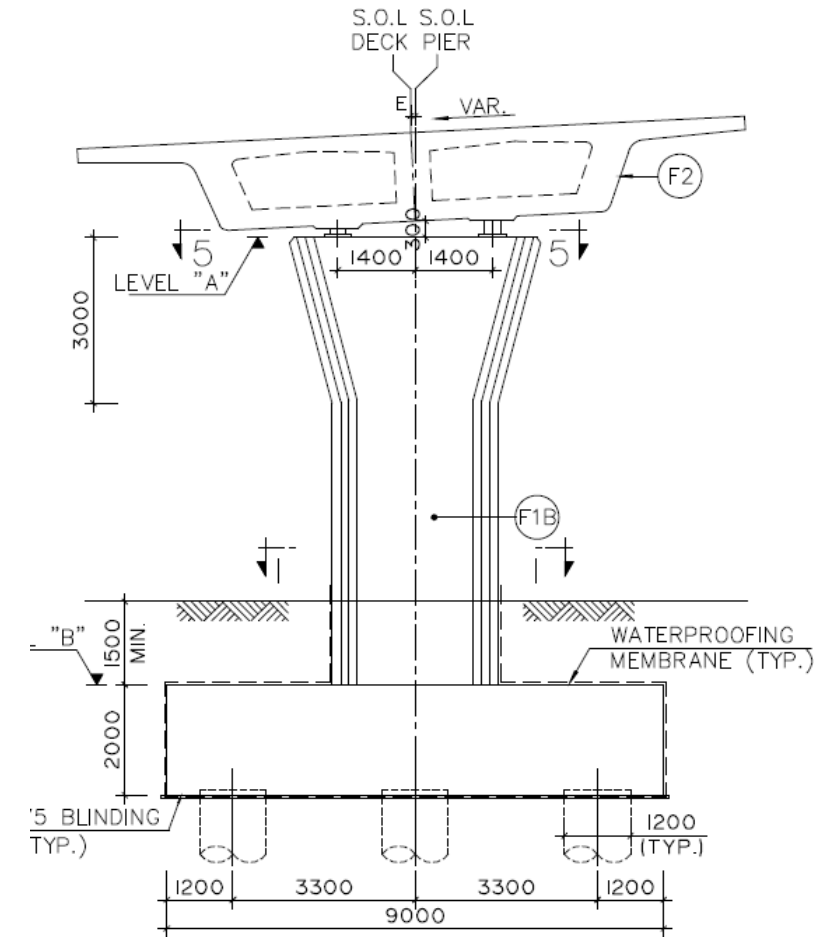
- Shallow Footings
- Abutments, bents, and piers are typically built on spread footings. Spread footings are large blocks of reinforced concrete that provide a solid base for the substructure and anchor the substructure against lateral movements.



Shallow footing

Components definition

- Pile Cap
- When the soils beneath a footing are not capable of supporting the weight of the structure above the soil, bearing failure occurs. The foundation shifts or sinks under the load, causing structure movement and damage.
- In areas where bearing failure is likely, footings are built on foundation piling.

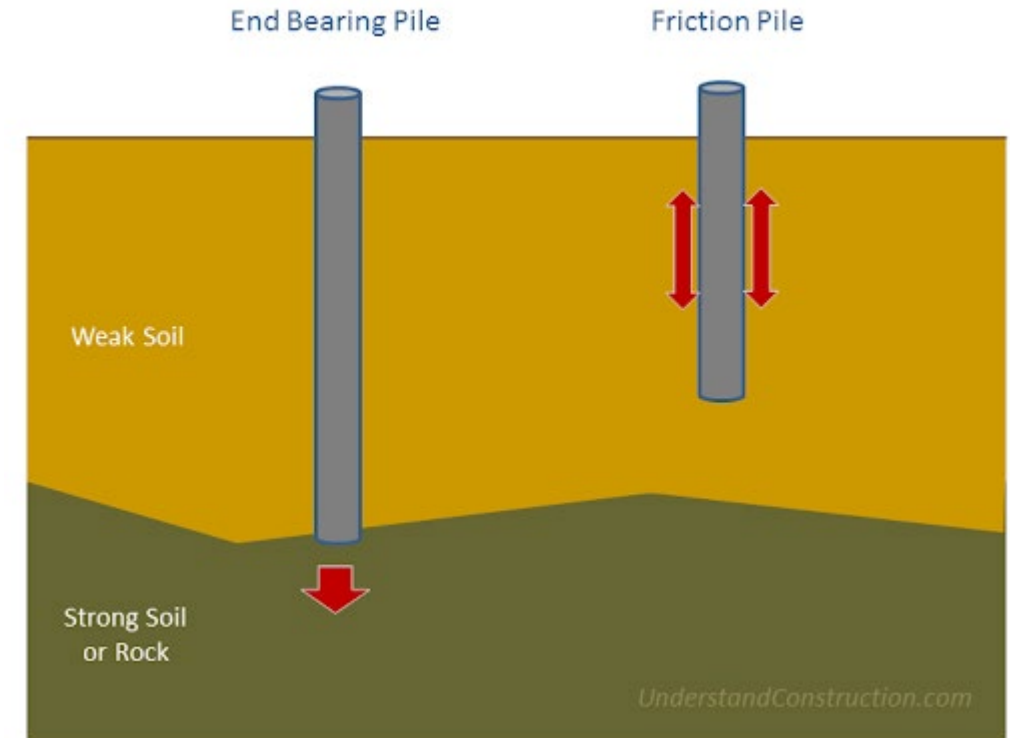


Pile cap

Bridge component definitions

Components definition

- Pile
- These load-bearing members are driven deep into the ground at footing locations to stabilize the footing foundation. Piling transmits loads from the substructure units down to underlying layers of soil or rock.

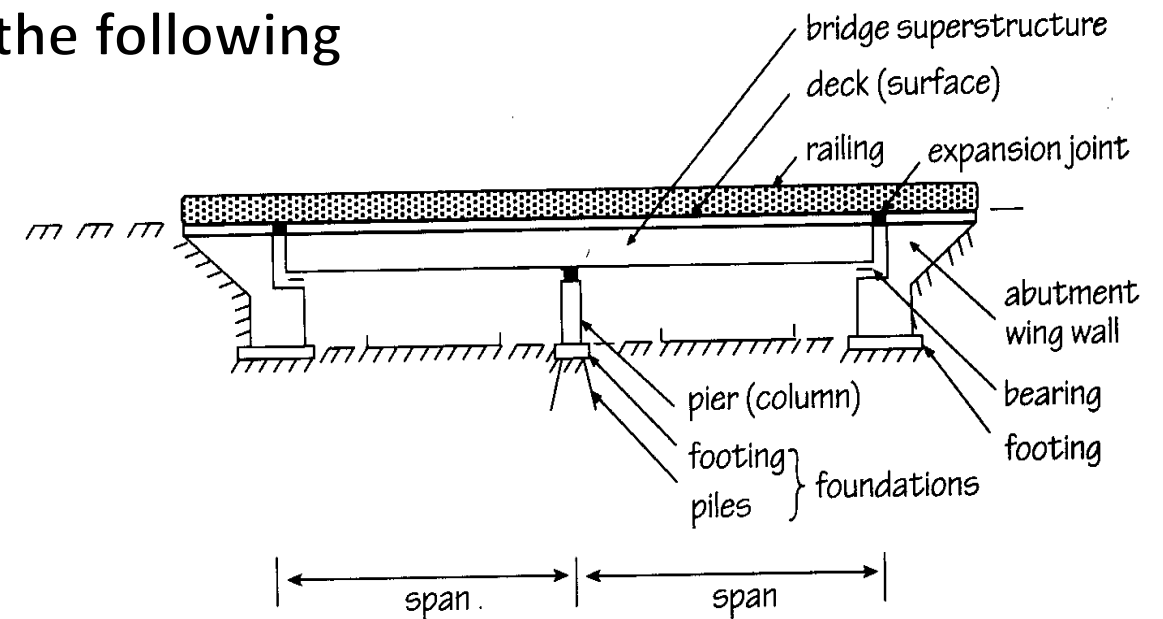


Pile types

Bridge component definitions

Components definition

- Super Structure
- The superstructure consists of the components that actually span the obstacle the bridge is intended to cross and includes the following
- Deck girder.
- Deck slab.
- Diaphragms.
- Railing.

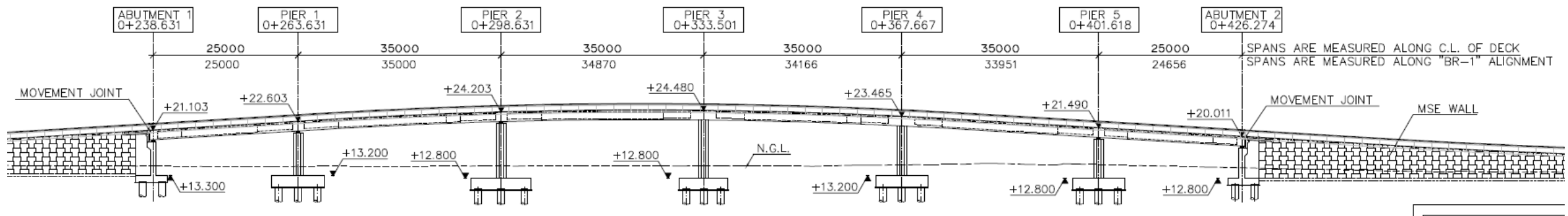


TYPICAL BRIDGE ELEMENTS

Bridge component definitions

Components definition

- Deck
 - The deck is the roadway portion of a bridge, including shoulders. Most bridge decks are constructed as reinforced concrete slabs.
 - Bridge decks are required to conform to the grade of the approach roadway so that there is no bump or dip as a vehicle crosses onto or off of the bridge.



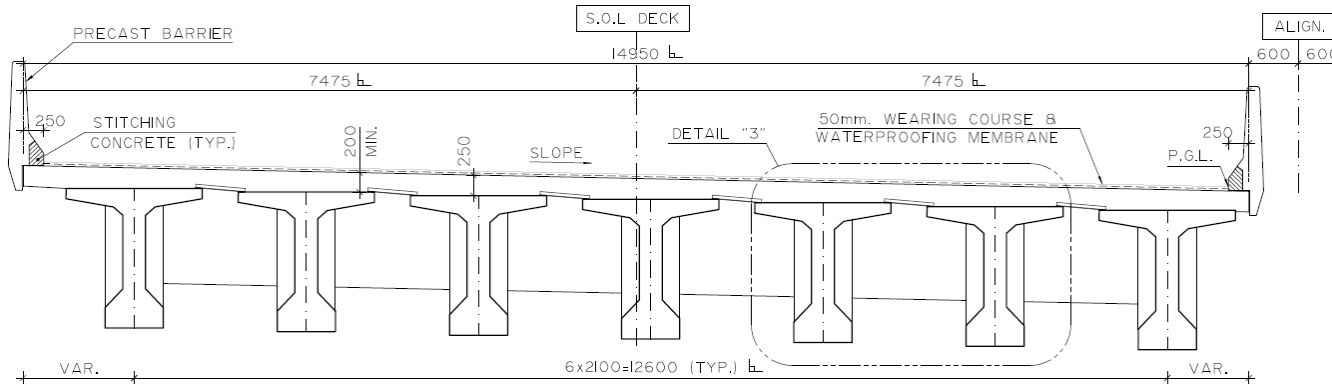
- Girder Type Bridge (girder plan)



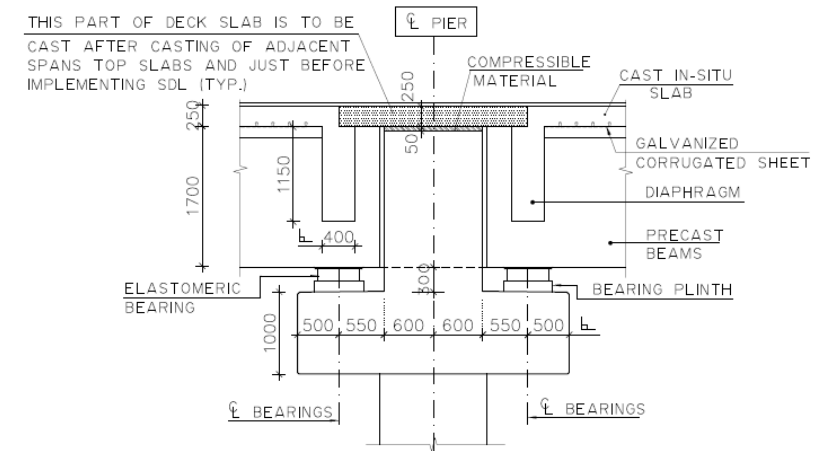
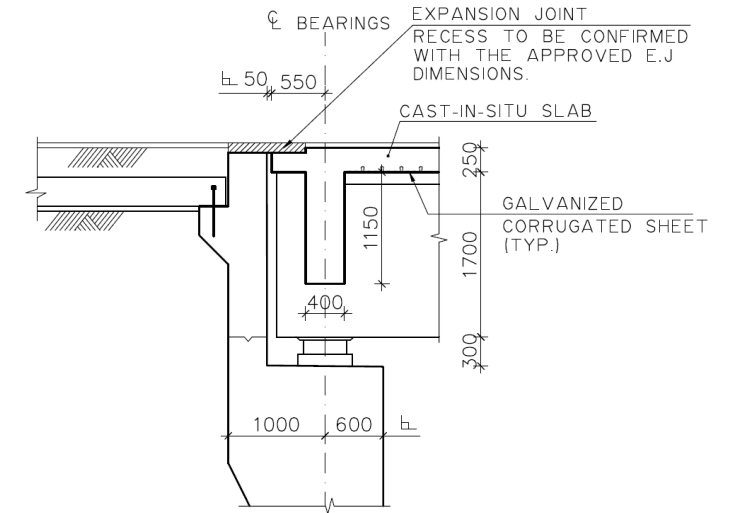
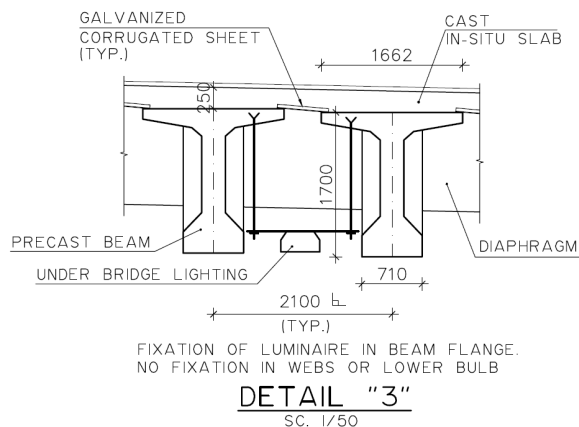
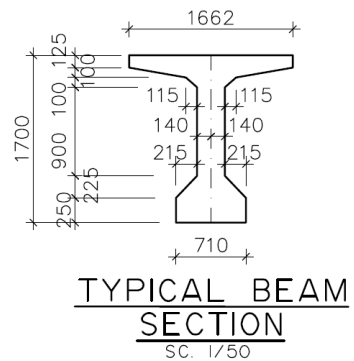
Bridge component definitions

Components definition

• Girder Type Bridge (deck general arrangement)



SECTION A-A
SC. 1/50



Bridge component definitions

Components definition

- Girder Type Bridge



Bridge component definitions



Components definition

- Cable profile**

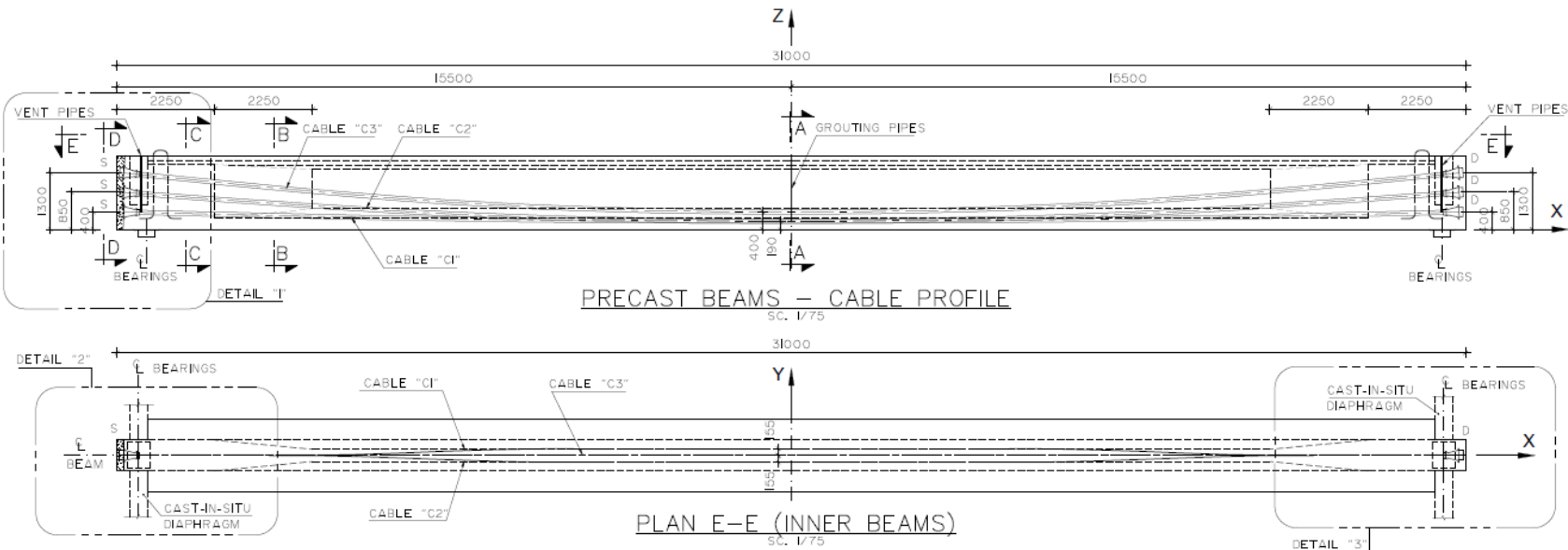
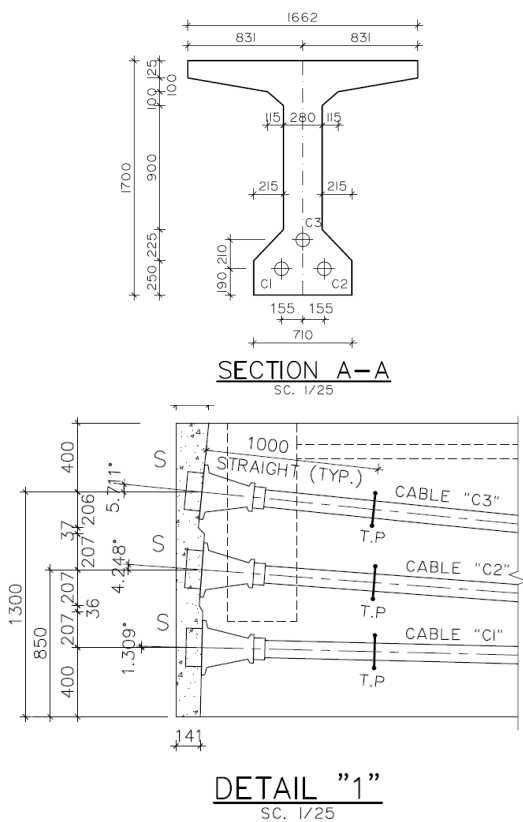


TABLE OF CABLE COORDINATES

		DIST. X FROM MIDSPAN OF BEAM	-15500	-15350	-15000	-14000	-13000	-12000	-10000	-9000	-8000	-7000	-6000	-5000	-4000	-3000	-2000	-1000	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	15500
DIST. Y	DIST. "Z"	CABLE "C1"	400	392	368	344	322	300	280	261	244	230	218	209	201	196	193	191	190	191	193	196	201	209	218	230	244	261	280	300	322	344	368	392	400
		CABLE "C2"	850	824	750	677	607	539	476	418	365	320	282	252	228	211	199	192	190	192	199	211	228	252	282	320	365	418	476	539	607	677	750	824	850
		CABLE "C3"	1300	1265	1163	1063	967	874	788	708	637	575	524	483	451	427	412	403	400	403	412	427	451	483	524	575	637	708	788	874	967	1063	1163	1265	1300
DIST. Y	DIST. "Z"	CABLE "C1"	0	0	0	0	0	2	22	57	95	129	151	155	155	155	155	155	155	155	155	155	155	155	151	129	95	57	22	2	0	0	0	0	0
		CABLE "C2"	0	0	0	0	0	-2	-22	-57	-95	-129	-151	-155	-155	-155	-155	-155	-155	-155	-155	-155	-155	-151	-129	-95	-57	-22	-2	0	0	0	0	0	0
		CABLE "C3"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bridge component definitions

Components definition

- Prestressing (pre-tension)



Pre-tension

Bridge component definitions

Components definition

- Prestressing (post tension)

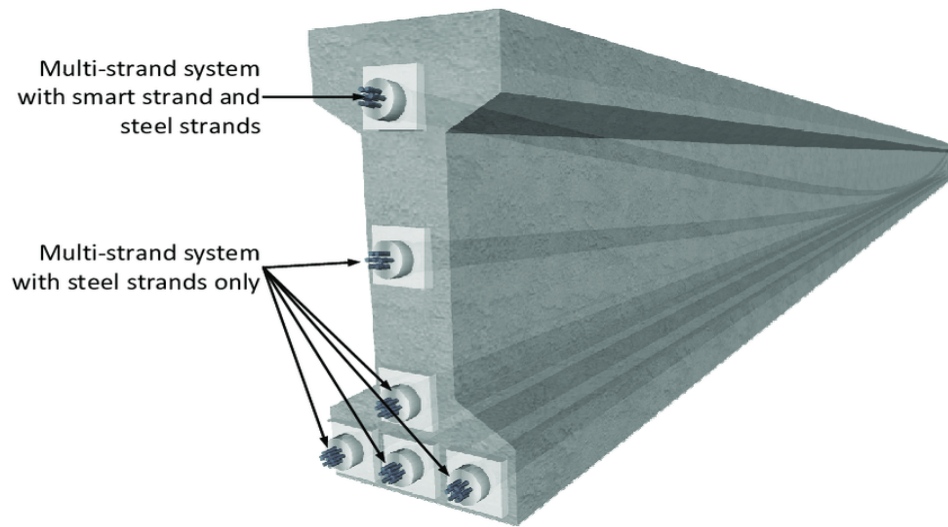


Post-tension

Bridge component definitions

Components definition

- Prestressing (post tension)

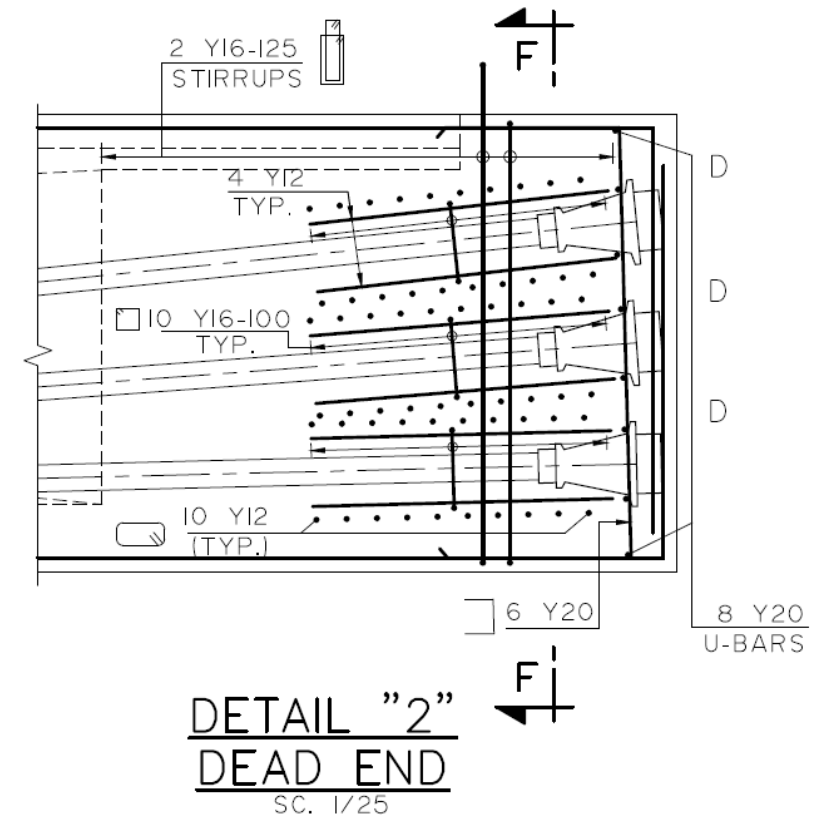
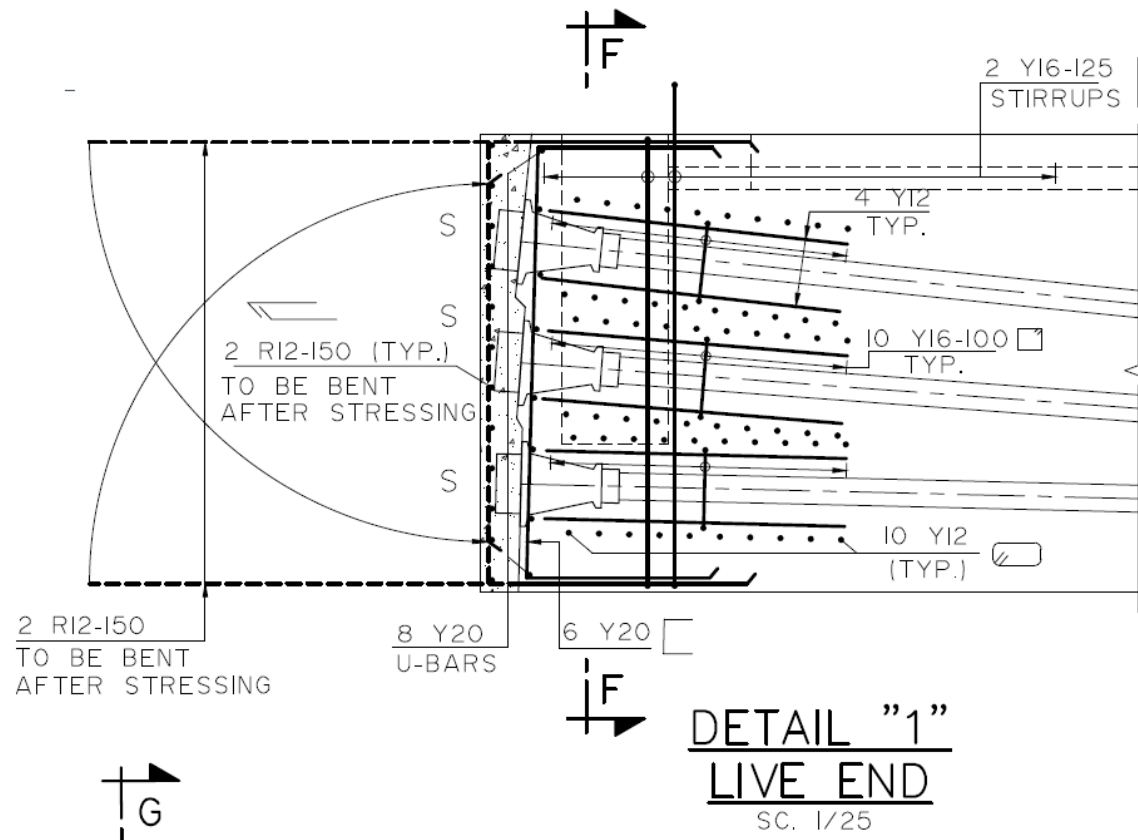


Post-tension

Bridge component definitions

Components definition

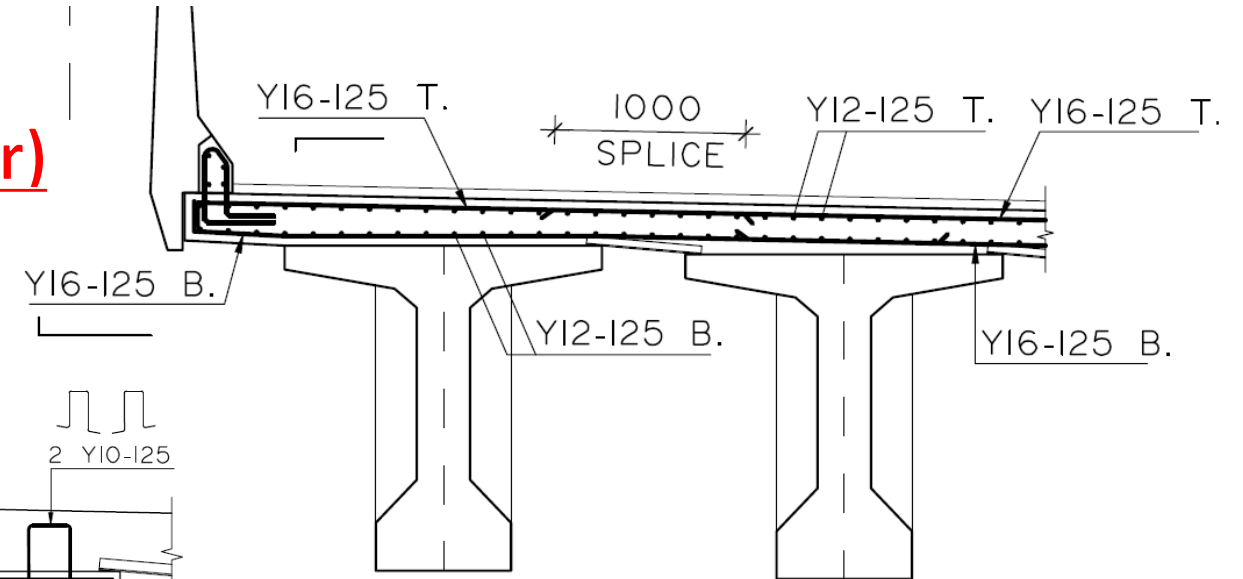
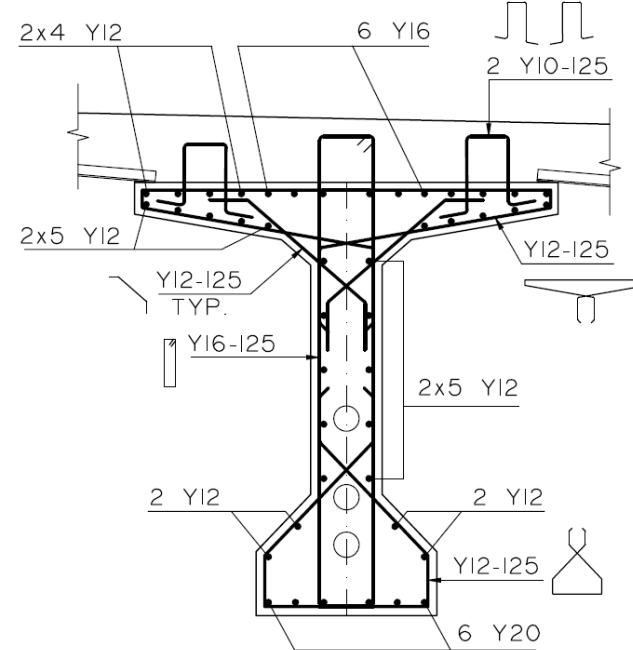
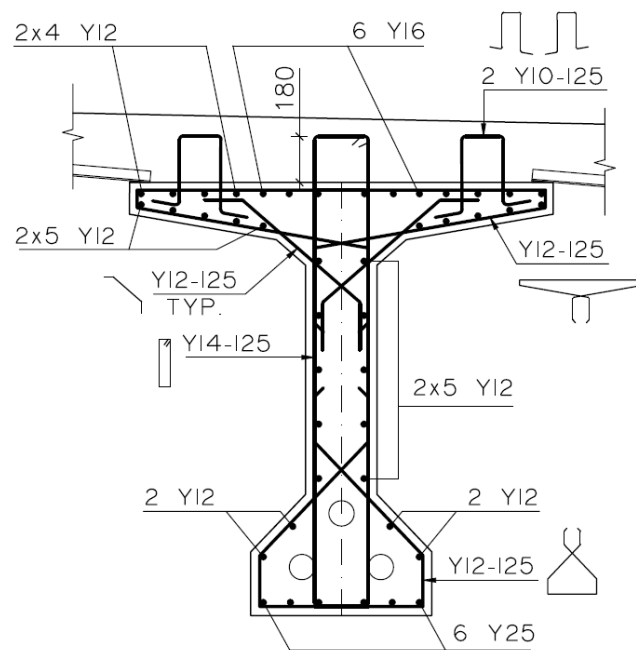
- Reinforcement (prestressing)



Bridge component definitions

Components definition

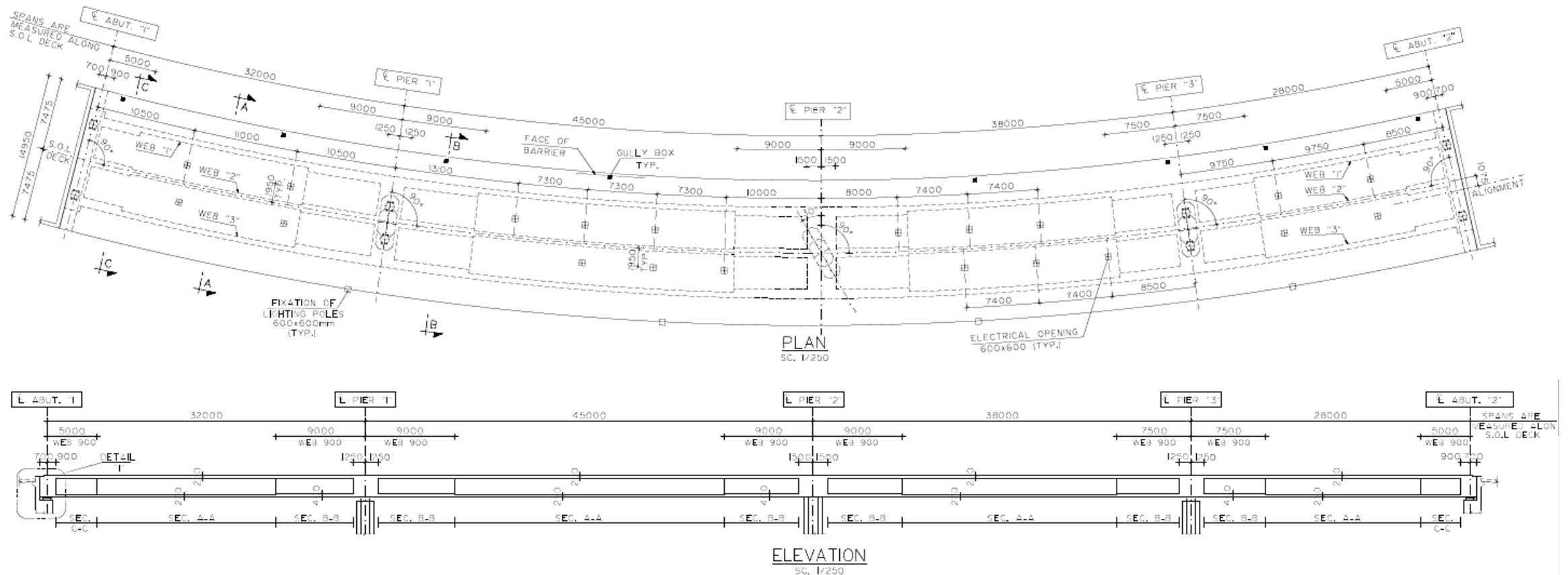
- Reinforcement (shear connector)
- Top Slab reinforcement



Bridge component definitions

Components definition

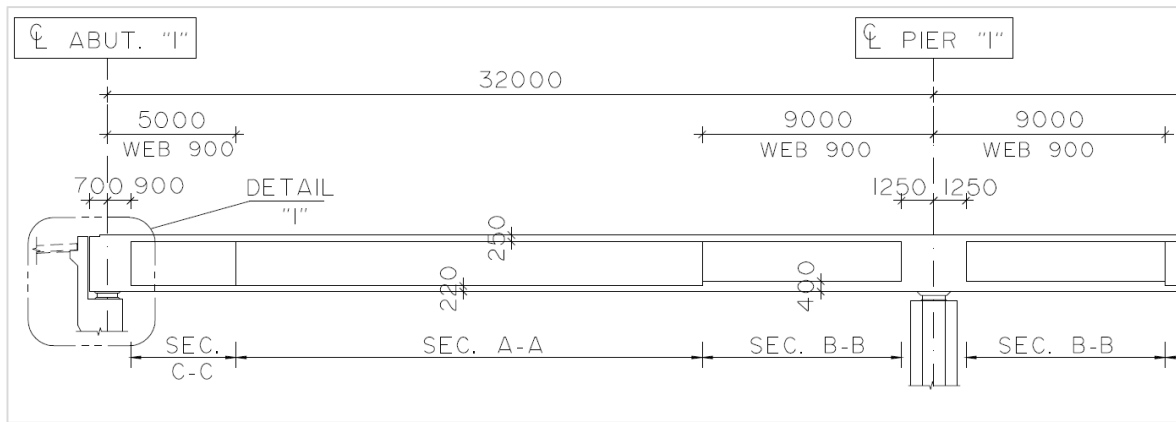
- Box girder deck



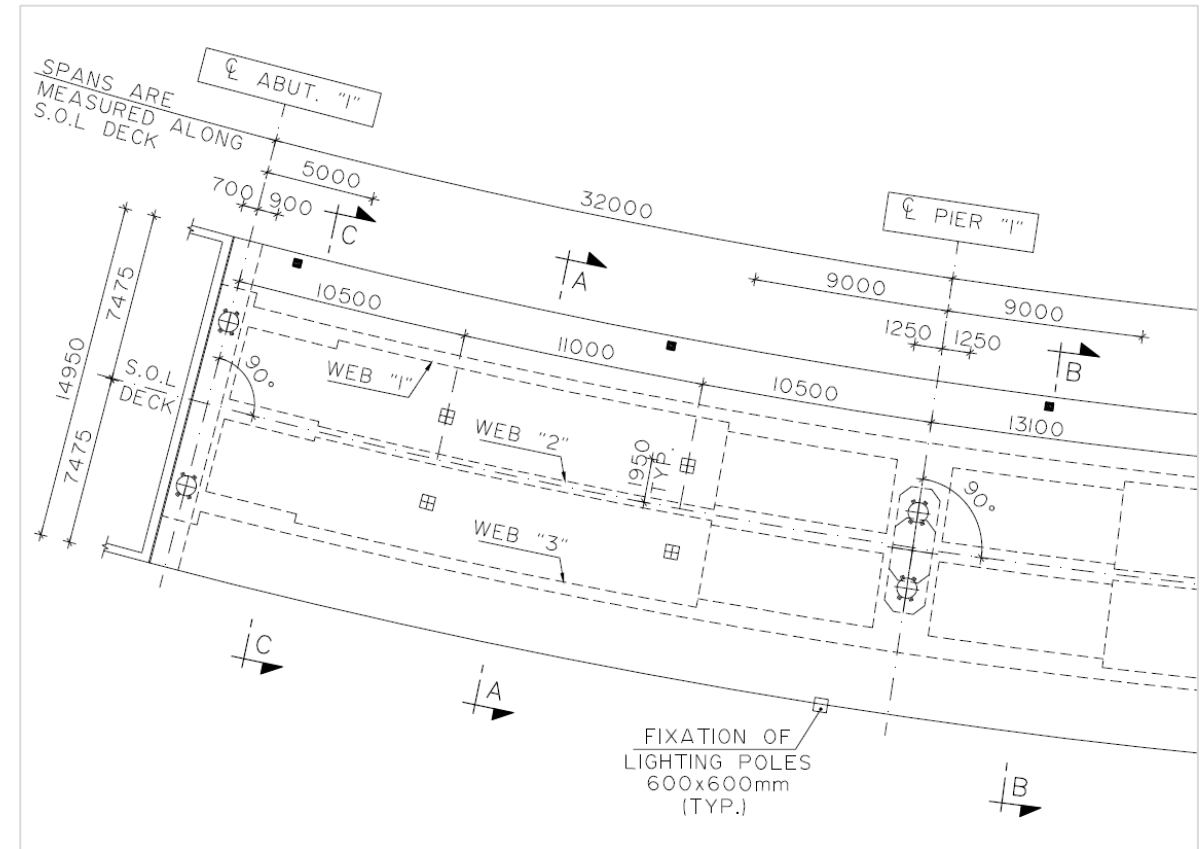
Bridge component definitions

Components definition

- Box girder deck



Part elevation – box girder bridge

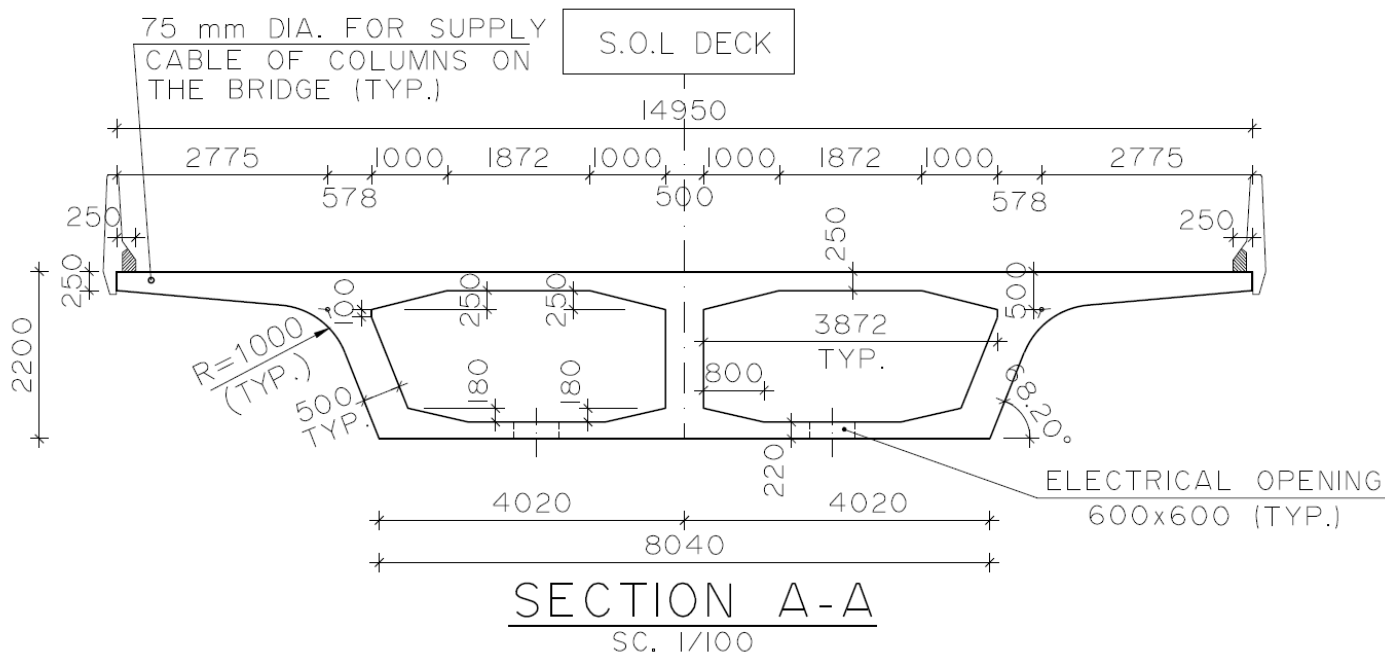


Part plan – box girder bridge

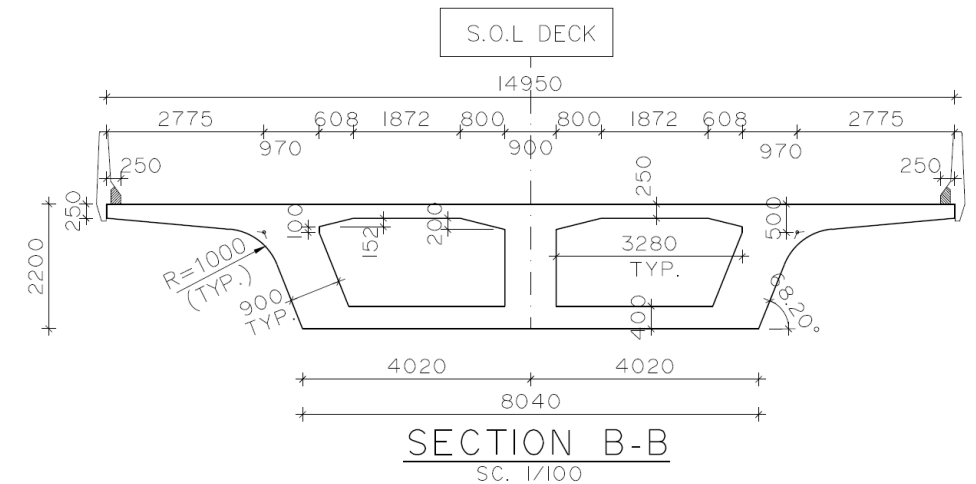
Bridge component definitions

Components definition

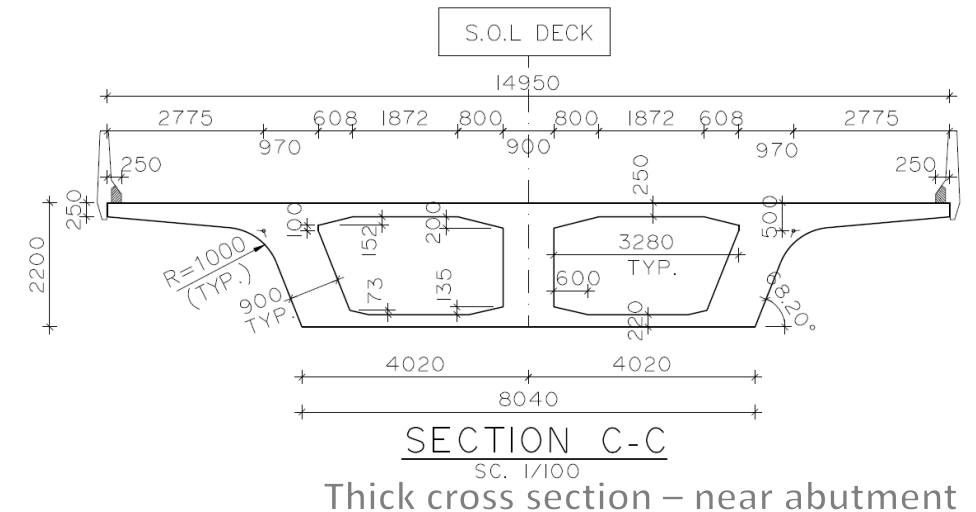
- Box girder cross section along bridge**



Typical cross section – near mid span



Thick cross section – near interior support



Thick cross section – near abutment

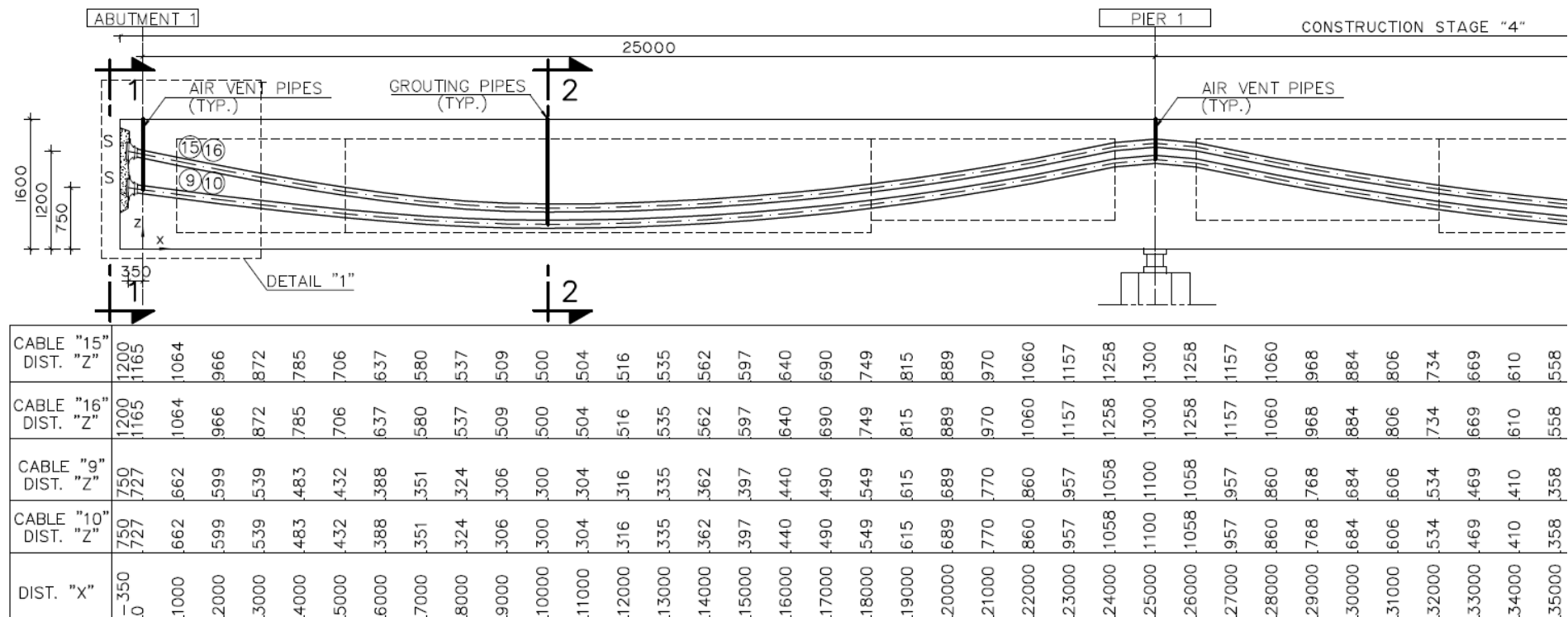
- Box girder deck prestressing (control points)



Bridge component definitions

Components definition

- Box girder deck prestressing (full profile table)

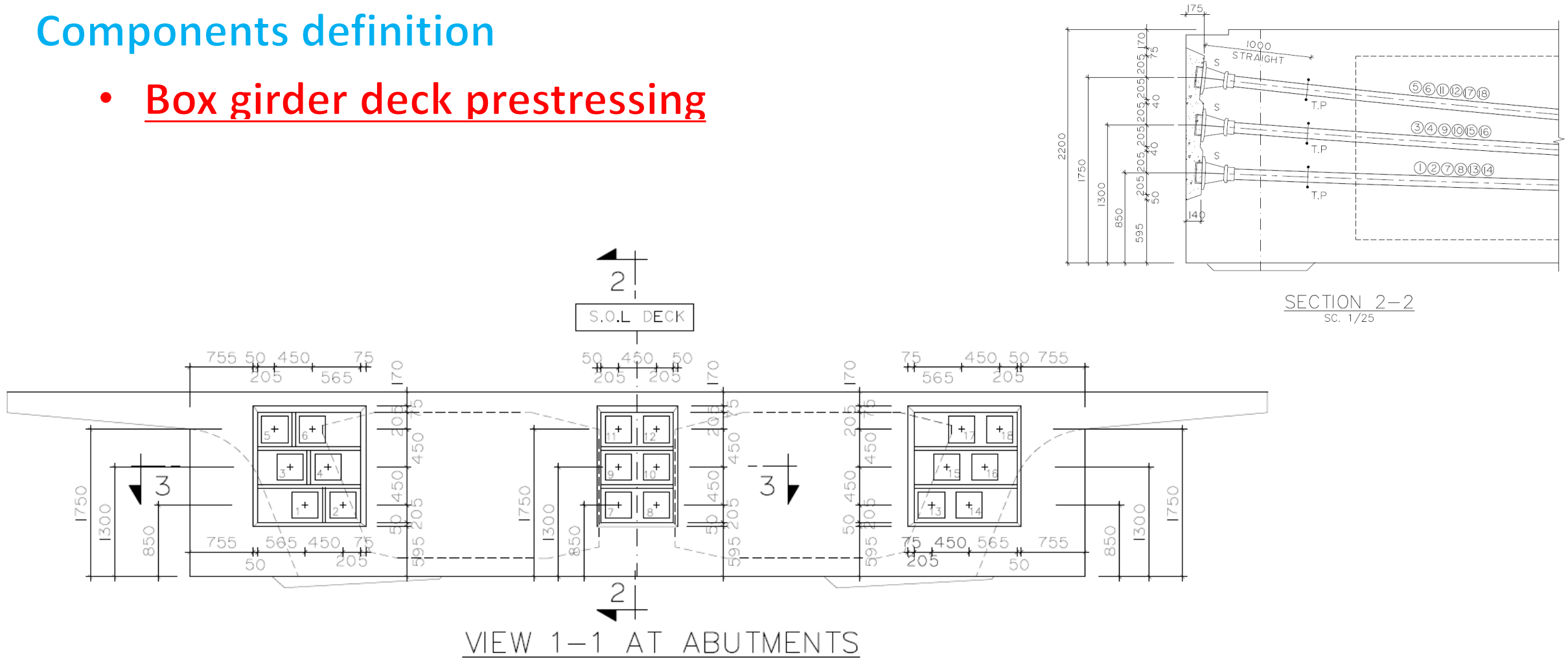


Box girder Prestressing – profile with full profile table

Bridge component definitions

Components definition

- Box girder deck prestressing



- Box girder deck reinforcement



PRELIMINARY DESIGN

PRELIMINARY DESIGN

- The time invested in preparing the preliminary design of a bridge is perhaps the most critical period in the design process.
- The designers must take time to properly and meticulously consider all factors that influence the project. These factors transcend purely utilitarian and first-cost considerations.

Choose the proper structure type.

- In the following subsections, the general characteristics of the common types of concrete bridge structures are given for reference in preliminary studies.
- the span-to-depth ratio and span lengths refer to highway bridges only. Bridges carrying railroads generally have smaller span-to-depth ratios and shorter spans.
- Whenever traffic beneath the proposed bridge has to be maintained during construction, the use of cast-in-place concrete may require special falsework. Falsework bents adjacent to the traffic should be protected.

Structure type

Choose the proper structure type.



Falsework with opening for traffic

Choose the proper structure type.

- In general, continuous structures with as few joints as possible should be selected.
- joints usually lead to higher initial costs and are the source of problems and higher maintenance costs in bridges.
- Decreasing the number of joints also helps to provide a smoother ride.
- spacing of joints as large as (200 m) have been used successfully.



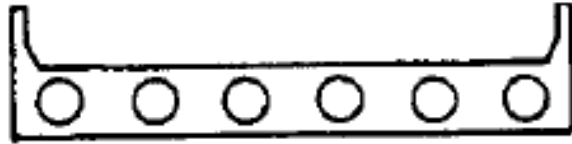
Expansion joint problems

Structure type

Non-prestressed concrete slab bridges



Solid Slab



Voided Slab



<u>Types</u>	<u>Span ranges</u>	
	<u>Highway</u>	<u>Railroad</u>
Solid slabs	16 to 44 ft (5 to 14 m)	12 to 24 ft (4 to 8 m)
Cored or voided slabs	40 to 65 ft (12 to 20 m)	20 to 40 ft (6 to 12 m)
Waffle soffit slabs	40 to 80 ft (12 to 24 m)	Not used

<u>Depth-to-span ratios</u>		
Simple spans	1/15±	1/12±
Continuous spans	1/20 to 1/24	1/16±

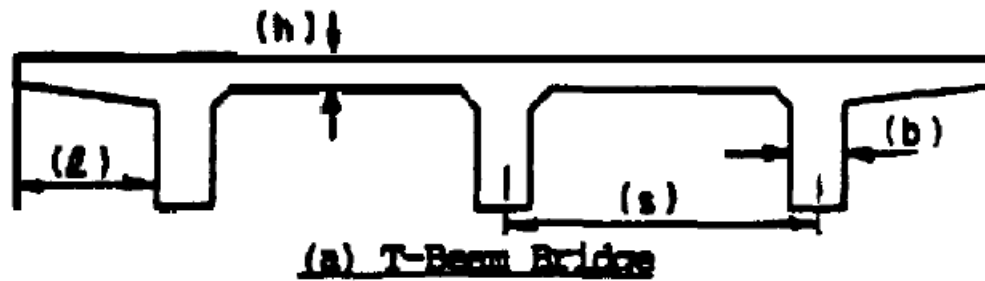
Appearance: Neat and simple; desirable for short spans.

Construction: Simplest type for details and formwork.

Construction time: Shortest of any cast-in-place construction.

Non-prestressed concrete slab bridges (Span to depth ratio)

Non-prestressed concrete girder bridges – T-beam



	Span ranges	
	Highway	Railroad
	30 to 120 ft (9 to 36.5 m)	20 to 40 ft (6 to 12 m)
	Depth-to-span ratios	
	Simple spans	1/13±
	Continuous spans	1/15±
		1/8±
		1/10±

Appearance: Elevation is neat and simple. Bottom is cluttered. Horizontal widening of stems at piers is detracting. If required, the exterior girder should be designed with the widening on the inside face. Utilities, pipes, and conduits can be concealed between girders.

Construction: Requires a good finish on all surfaces; formwork may be complex.

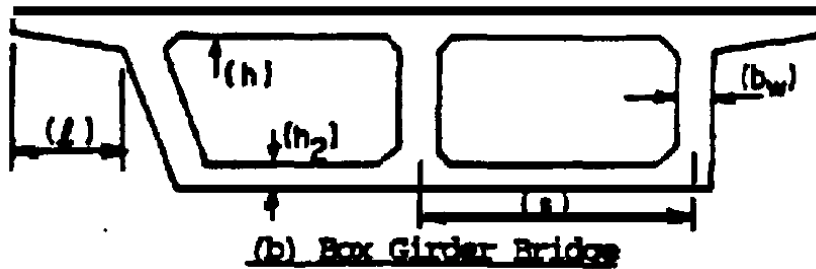
Construction time: Usually somewhat longer than required for slab bridges due to more complex forming.

Maintenance: Low, except that bearing and transverse deck joint details may require attention. At stream crossings, with inadequate underclearance, floating debris may damage the girder stems.

Non-prestressed concrete girder bridges – T-beam (Span to depth ratio)

Structure type

Non-prestressed concrete box girder



Span ranges

<u>Highway</u>	<u>Railroad</u>
80 to 200 ft (24 to 60 m)	50 to 100 ft (15 to 30 m)

Depth-to-span ratios

	<u>Highway</u>	<u>Railroad</u>
Simple	1/14±	1/11±
Continuous	1/18±	1/14±

Appearance: Neat and clean lines from all views; utilities, pipes, and conduits can be concealed between girders or within boxes.

Construction: Rough form finish is satisfactory on inside surfaces but removal of upper slab forming and supports is difficult and the material may be left inside.

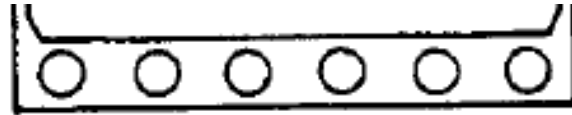
Construction time: More than required for slab or T-Beam bridges due to staging of concrete placement.

Non-prestressed concrete box girder (Span to depth ratio)

Prestressed concrete slab bridges - Cast-in-place post-tensioned



Solid Slab



Voided Slab

Appearance: Neat and simple; desirable for relatively short spans.

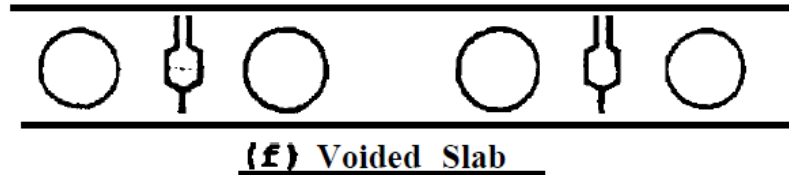
Construction: More complex than nonprestressed concrete. Sequence of prestressing and grouting requires supervision by specialists.

Construction time: Usually longer than as nonprestressed concrete slabs, because of draping of conduit, placing of anchors, attaining strength, and tensioning operations.

Type	Span ranges	
	Highway	Railroad
Solid slabs	Up to 100 ft (30.5 m)	Up to 20 ft (6 m)
Cored or voided slabs	Up to 150 ft (46 m)	Up to 40 ft (12 m)
Partial box voided slabs (slabs which typically are solid over the supports and a certain distance to each side, but voided at the central portion of the span)	Over 150 ft (46 m)	No data available
	Depth-to-span ratios	
	Simple	Continuous
	1/20±	1/16±
	1/24 to 1/40*	1/18±

Prestressed concrete slab bridges (Span to depth ratio)

Prestressed concrete slab bridges - Precast pretensioned



<u>Types</u>	<u>Span ranges</u>	
	<u>Highway</u>	<u>Railroad</u>
Solid slabs	19 to 30 ft (6 to 9 m)	12 to 20 ft (4 to 6 m)
Cored slabs	30 to 80 ft (9 to 24 m)	24 to 40 ft (8 to 12 m)

Depth-to-span ratio

1/25 to 1/33

1/20 ±

Appearance: Neat and simple; desirable for low short spans.

Construction: Details and formwork very simple; plant fabrication methods are suitable; field erection may be fast.

No falsework required; units placed by cranes; no prolonged impediment to traffic.

Construction time: Time for erection of precast elements at site is minimal.

Prestressed concrete slab bridges (Span to depth ratio)

Prestressed concrete girder bridges - Cast-in-place, post-tensioned

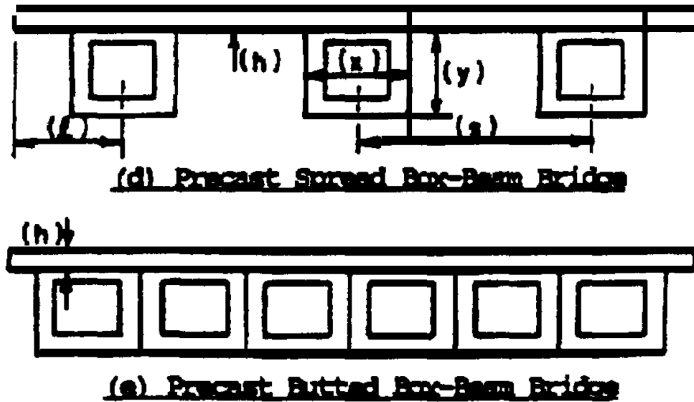
<u>Types</u>	<u>Span ranges</u>	
	<u>Highway</u>	<u>Railroad</u>
Constant-depth beams	40 to 120 ft (12 to 36 m)	Up to 80 ft (24 m)
Constant-depth box beams	80 to 300 ft (25 to 90 m)	Up to 110 ft (30 m)
Haunched beams	up to 200 ft (61 m)	No data available
Haunched box beams	Up to 700 ft (215 m)	No data available
	<u>Depth-to-span ratios</u>	
	Simple spans	1/22±
	Continuous spans	1/25 to 1/33
	Haunched girders	1/33 to 1/50
		No data available

Appearance: From below, T-beams appear cluttered while a box girder is neat and clean, making it more attractive; elevation of both types is neat and simple. Bent caps should be hidden between girders. Drop caps should be avoided for best appearance.

Construction time: Somewhat longer than for nonprestressed concrete T-beam or box girder bridges.

Prestressed concrete girder bridges (Span to depth ratio)

Prestressed concrete girder bridges - Precast T-Beam, I-girder, and box girder



Construction: Longer span girders are more difficult to handle after fabrication in plant and at job site; standard girders are preferred; special sections are usually more expensive; standard forms are stocked by fabricators; members can be used as simple spans, but preferably girders should be made continuous for live load.

Construction time: Erection time for precast elements at site is minimal, but formwork may be required for slabs between girders.

Highway	Railroad
Span range	
30 to 160ft (9 to 50 m)	Up to 110ft (33 m)
Depth-to span ratios	

T-beam and I-girder

Simple spans	1/18±	1/14±
Continuous spans	1/20±	1/16±

Spread box girder

Simple spans	1/18±	Not used
Continuous spans	1/22±	Not used

Butted box girder

Simple spans	1/25±	1/16±
Continuous spans	1/28±	1/18±

Precast box beams ordinarily have a width x of 3 to 4 ft (0.9 to 1.2 m), and heights y of 1 ft-9 in. to 4 ft (0.5 to 1.2 m).

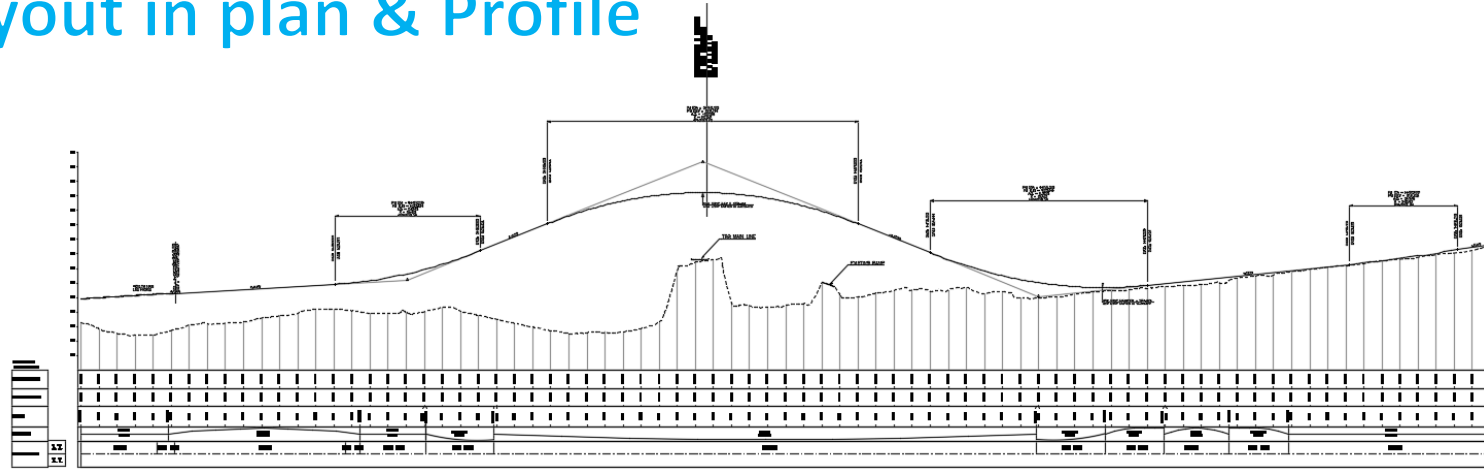
Appearance: I-beam is similar to T-beam, except for bulbous bottom of standard prestressed girder sections; spread

Prestressed concrete girder bridges (Span to depth ratio)

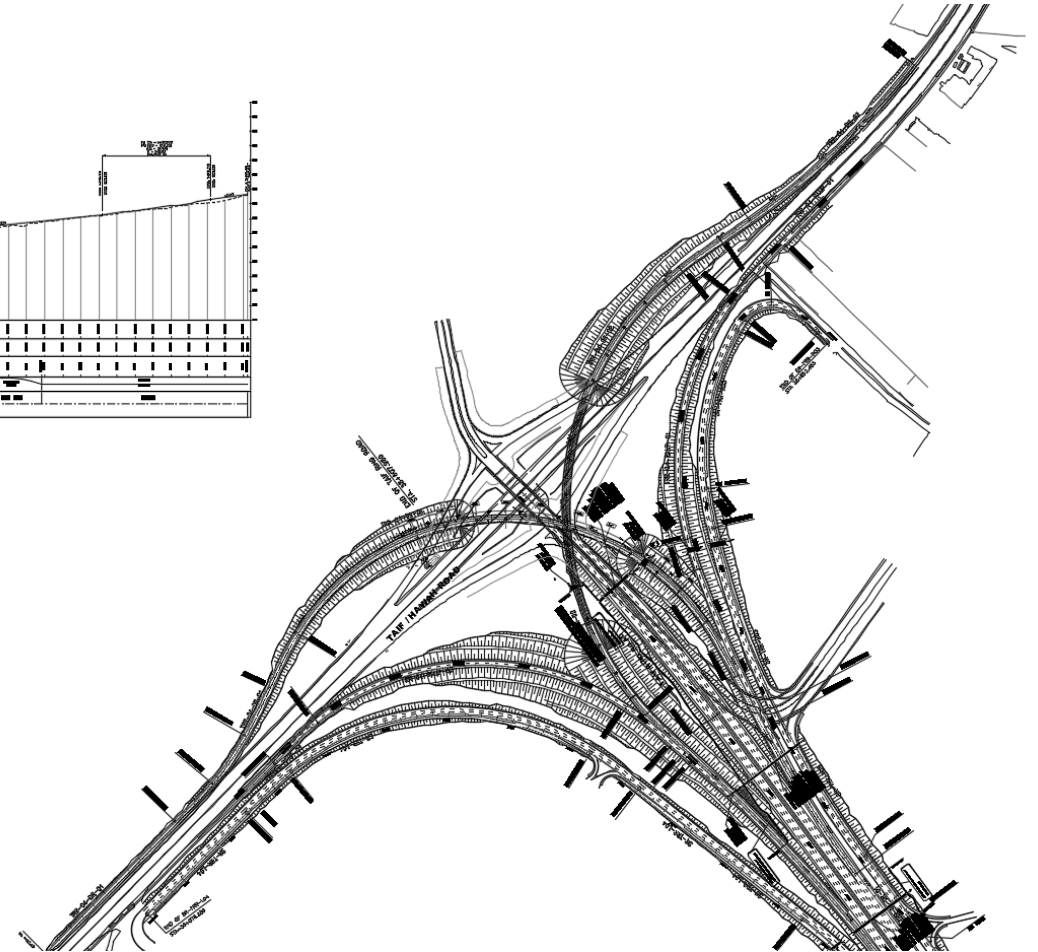
Bridge layout & number of lanes

Transportation Design

Layout in plan & Profile



FINISHED GROUND	1519.830	1519.982	1520.133	1520.285	1520.436	1520.552	1520.683	1520.827
EXISTING GROUND	1516.59	1515.72	1515.06	1514.80	1514.88	1515.48	1516.23	1516.43
STATION	0+000.000	0+025	0+050	0+075	0+100	0+120.714 0+125	0+150	0+175
ALIGNMENT	TANGENT L=120.714							
SUPERELEVATION	L.T.	1.50%				S.E. APP.		
	R.T.							



Road way width & Super Elevation

Derive $h = \frac{Bv^2}{gR}$

$\phi_1 = \phi_2$

$\tan \phi_1 = \tan \phi_2$

$\frac{h}{B} = \frac{P}{W}$

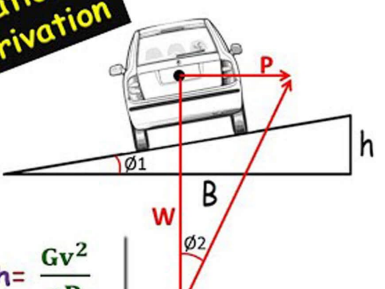
$\cancel{B} \times \frac{h}{\cancel{B}} = \frac{v^2}{gR} \times B$

$h = \frac{v^2}{gR} \times B$

$\frac{P}{W} = \frac{v^2}{gR}$

$\tan \phi = \frac{\text{per base}}{\text{rise Run}}$

Super elevation's formula derivation

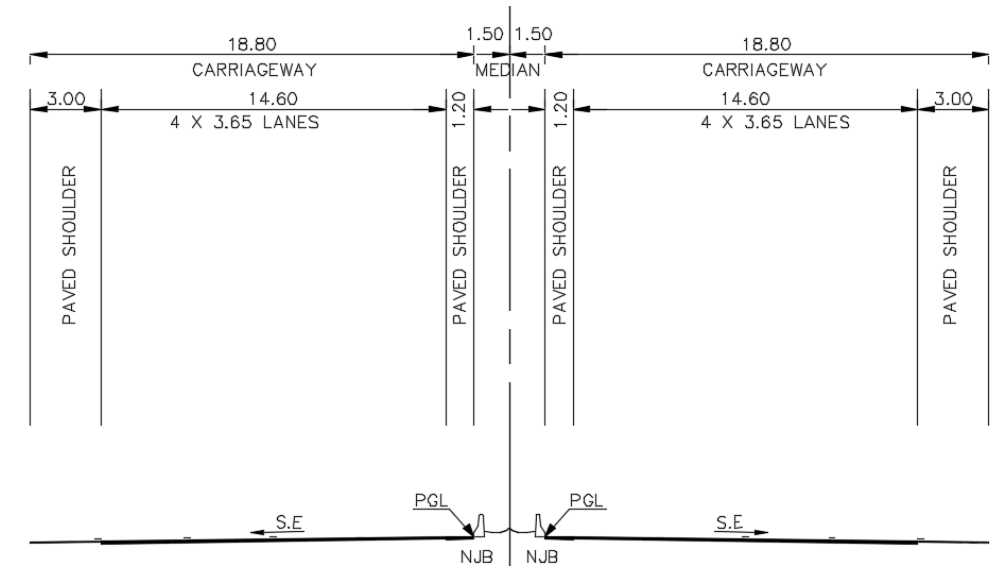
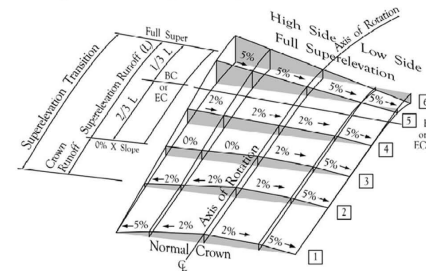


$h = \frac{Bv^2}{gR}$

$h = \frac{Gv^2}{gR}$



Super-elevation Transition

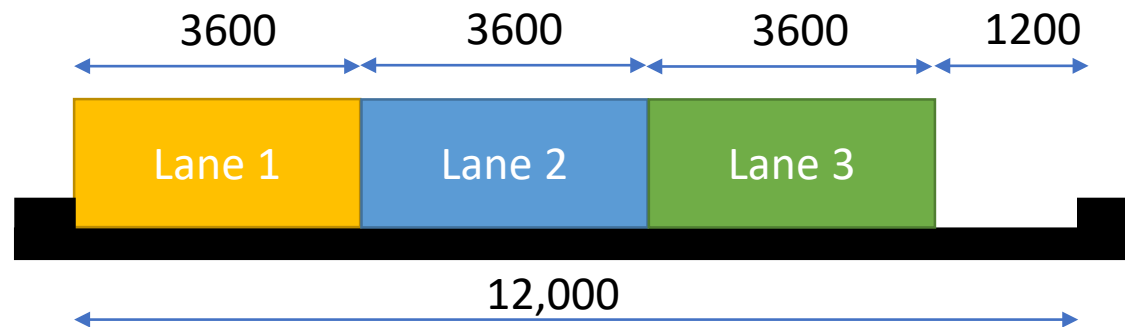


Number of design lanes

- Generally, the number of design lanes should be determined by taking the integer part of the ratio $w/3600$,
- where w is the clear roadway width in mm between curbs and/or barriers.
- Possible future changes in the physical or functional clear roadway width of the bridge should be considered.
- In cases where the traffic lanes are less than 3600 mm wide, the number of design lanes shall be equal to the number of traffic lanes, and the width of the design lane shall be taken as the width of the traffic lane.

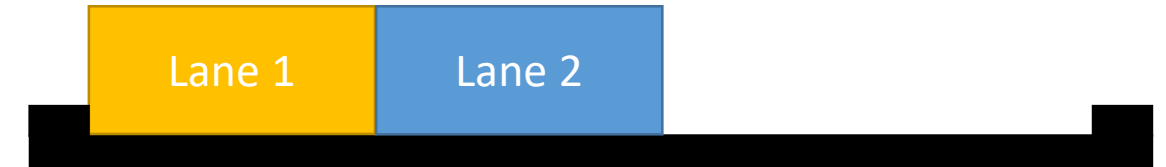
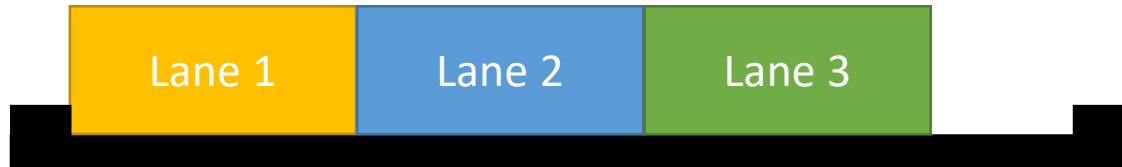
Number of design lanes

- Roadway widths from 6000 to 7200 mm shall have two design lanes, each equal to one-half the roadway width.
- Assume bridge width = 12,000 mm
- Number of lanes = $12000/3600 = 3.33$ (number of lanes 3)



Number of design lanes

- The extreme live load force effect shall be determined by considering each possible combination of number of loaded lanes account for the probability of simultaneous lane occupation



Multiple Presence of Live Load

- The equations are based on evaluation of several combinations of loaded lanes with their appropriate multiple presence factors and are intended to account for the worst case scenario.

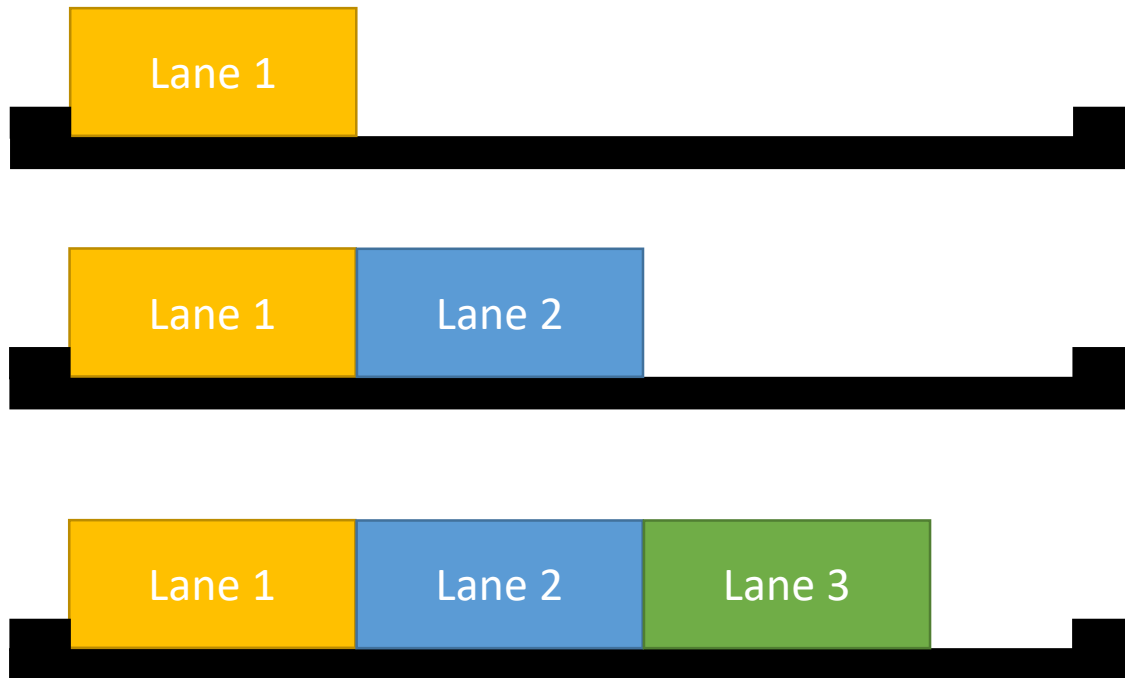


Table 3.6.1.1.2-1—Multiple Presence Factors, m

Number of Loaded Lanes	Multiple Presence Factors, m
1	1.20
2	1.00
3	0.85
>3	0.65

The entry greater than 1.0 in Table 3.6.1.1.2-1 results from statistical calibration of these Specifications on the basis of pairs of vehicles instead of a single vehicle. Therefore, when a single vehicle is on the bridge, it can be heavier than each one of a pair of vehicles and still have the same probability of occurrence.